COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

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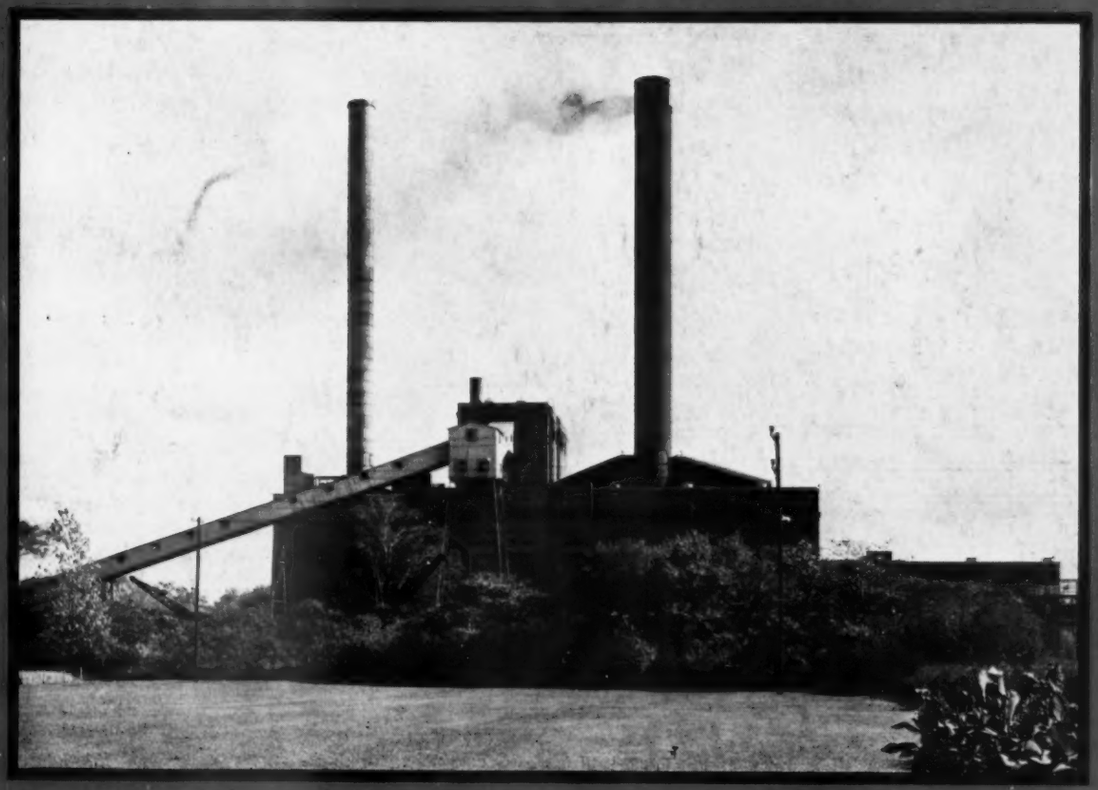


Dresser Station of Public Service Company of Indiana; see page 22

Dresser Station Adds 50,000 Kw

The Mercury-Vapor Process

Trends in Steam Plant Development

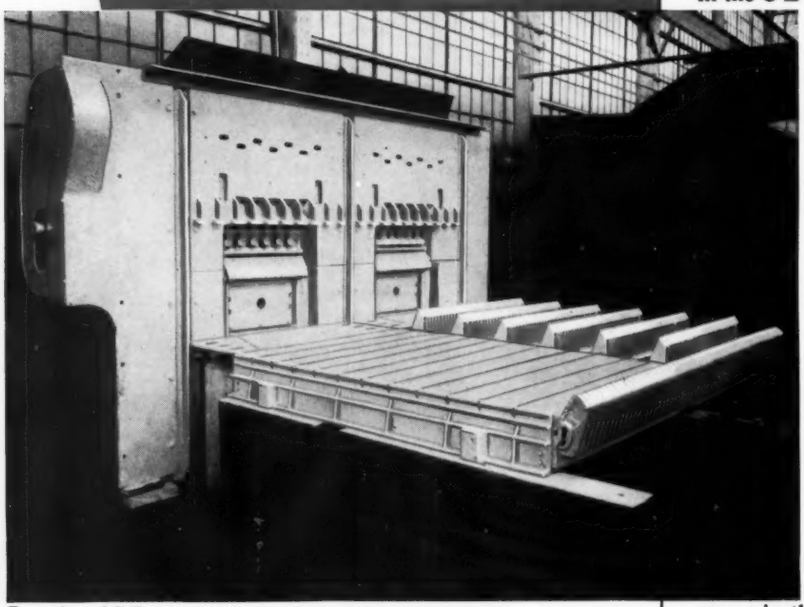
Lampblack Fired Under Boiler at Honolulu Gas Co., Ltd.

Utilizing Refuse Coals at 12th St. Station, Richmond, Va.

Don't Buy A Spreader Stoker

BEFORE EXAMINING THE FEATURES OF SUPERIORITY OFFERED BY C-E

If the nominal advantages of spreader stoker firing suit your problem—such as moderate first cost; consistently low maintenance; adaptability to a wide variety of low-cost fuel; sensitive response to load changes; limitations of installation space—you'll want to consider the points of superiority available in the C-E Spreader Stoker. Certain of the following features are exclusive with C-E, while others are distinct improvements over conventional spreader stoker design.

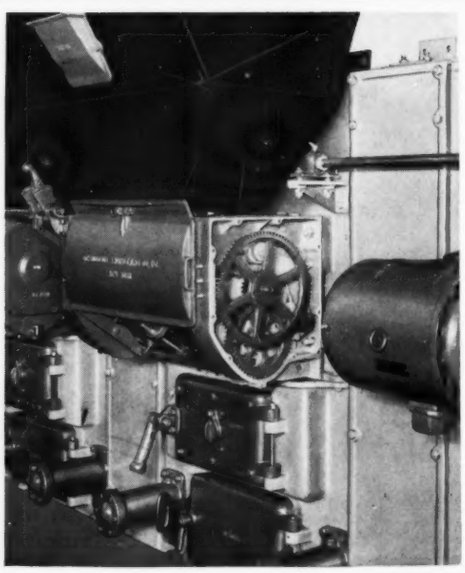


Rear view of C-E Spreader Stoker showing grate surface with one section in dumping position.

ROTARY FEEDER — non-clogging, non-avalanching type . . . handles wet or dry coal with equal effectiveness and insures a positive and steady flow of coal despite variations in size and moisture content . . . readily adapted to automatic control to maintain rate of coal feed in direct proportion to load.

ROTARY DISTRIBUTOR (OR SPREADER) — driven through variable-speed mechanism . . . distributor blades and their shafts are alloy steel to resist wear and corrosion . . . adjustable fuel tray in spreader assembly aids proper fuel distribution and compensates for wear of distributor blades . . . distributor rotor mounted on roller bearings which are protected from dust and lubricated through grease-gun fittings at stoker front . . . bearing housings are water-cooled.

UNIT CONSTRUCTION — each feeder and distributor unit is protected by a shear key conveniently located at the stoker front, and is driven through an individual clutch controlled by a hand lever which permits disconnecting both feeder and distributor of any unit for light-load operation, inspection and repairs. The operating mechanism is fully enclosed, and oil-tight housings protect all feeder drive parts which are constantly lubricated to provide quiet operation and minimize maintenance.



Complete accessibility of both controls and operating mechanism at the front of the C-E Spreader Stoker.

SECTIONALIZED GRATE SURFACE — consists of small flat-surfaced castings, deep ribbed for maximum cooling . . . easy replacement of inexpensive individual castings when necessary. Both stationary and dumping-type grates are available . . . dumping grates may be operated either manually or through steam power cylinders controlled by a simple valve. Zone air supply provides separate control of air to each grate unit.

These salient features are incorporated in a well-balanced design that is rugged and compact with particular emphasis on ready access to vital parts.

Existing installations of C-E Spreader Stokers, ranging from 4000 to 175,000 lb of steam per hr, indicate the extent of C-E's experience—not only in design and manufacture of the equipment itself, but also in proper application to boiler and furnace so as to insure *all* of the advantages of spreader firing.

More important, you can rely on C-E to offer impartial counsel regarding the suitability of the spreader stoker for your plant since C-E has available and can offer you any other type of industrial stoker.

A 582

COMBUSTION ENGINEERING

200 Madison Avenue New York, New York

C-E PRODUCTS INCLUDE ALL TYPES OF BOILERS, FURNACES, PULVERIZED FUEL SYSTEMS AND STOKERS; ALSO SUPERHEATERS, ECONOMIZERS AND AIR HEATERS

COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

VOLUME TWELVE NUMBER TEN

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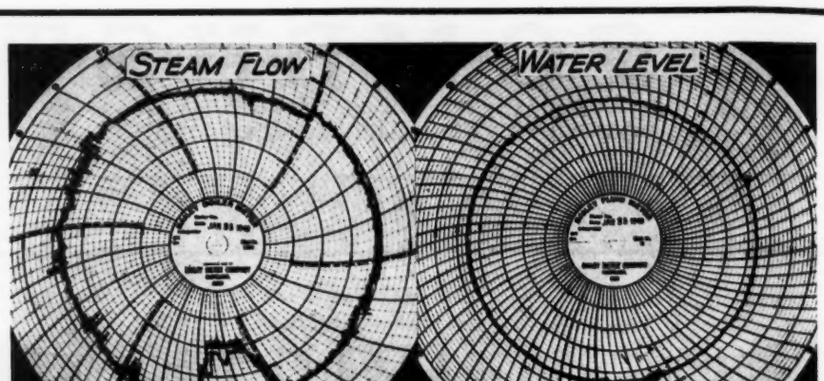
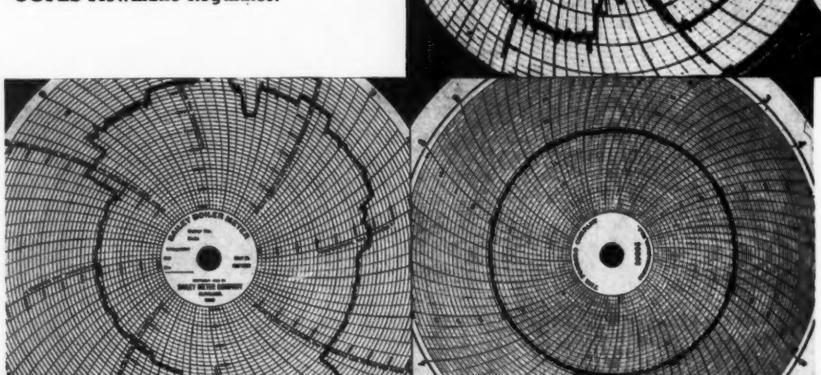
CCA

1300 POUNDS W.S.P.—

Fired with pulverized coal or oil, this 1300-pound B. & W. boiler in a prominent Eastern utility plant normally evaporates 275,000 pounds per hour with a maximum of 300,000 pounds. Excess water pressure at pump discharge is 250-300 pounds. The boiler water level is held within plus or minus one inch of the desired normal by the COPES Flowmatic Regulator.



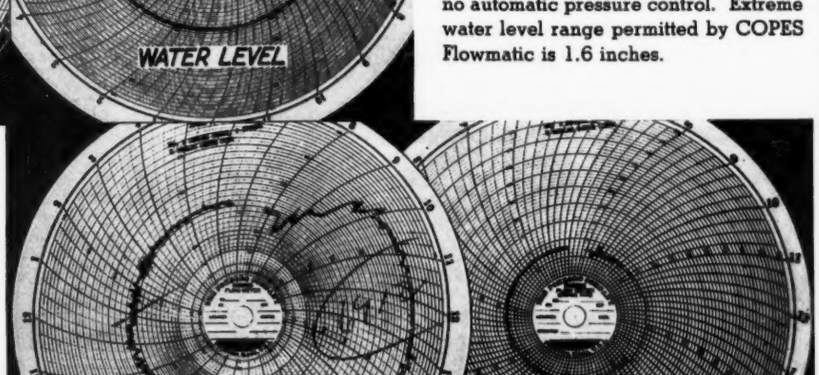


—875 POUNDS W.S.P.

Powdered coal firing. 875-pound, 860-degree, Foster Wheeler 3-drum boiler. The maximum evaporation with this utility boiler is 400,000 pounds per hour; normal, 330,000 pounds per hour. The motor-driven centrifugal pump has no automatic pressure control. Extreme water level range permitted by COPES Flowmatic is 1.6 inches.

600 POUNDS W.S.P.—

Firing with acid sludge or gas, normal evaporation is as high as 350,000 pounds per hour on this 600-pound pressure Riley Steam Generator. Boiler water level is carried one inch higher at peak load of 360,000 pounds per hour than at normal minimum of 242,000 pounds per hour. The level control by COPES Flowmatic is unusually close on all loads.



Why worry about water level?

The COPES Flowmatic is daily demonstrating close level control at pressures from 80 to 1325 pounds—for capacities up to 550,000 pounds per hour. Write for Bulletin 429, showing typical charts and explaining operation.

NORTHERN EQUIPMENT CO., 416 GROVE DRIVE, ERIE, PA.

Feed Water Regulators, Pump Governors, Differential Valves
Liquid Level Controls, Reducing Valves and Desuperheaters

★ GET CLOSER LEVEL CONTROL WITH THE COPES FLOWMATIC ★ REGULATOR

EDITORIAL

Burning a Variety of Coals

Accelerated defense production, potentialities of the war situation, the periodic adjustment of mine labor agreements and the operations of the Bituminous Coal Act, all tend to create uncertainties in the coal markets; so much so, that many are giving serious consideration to the possibilities of burning coals other than those for which plants and equipment have been designed. While the great diversity in coal characteristics makes it impossible to design fuel-burning equipment that will be universal in scope, recent studies and experience have demonstrated that a wider range of fuels is possible in some installations than had previously been considered feasible—that is, providing one is prepared to accept some sacrifice in thermal economy and perhaps inconvenience in order to assure a supply from several sources and take advantage of price.

In this connection the experience with many coals, some of the refuse type, at the 12th Street Station of the Virginia Electric and Power Company, as here related by Mr. Reich, is most timely. With the type of furnace and method of firing employed, he was able to burn a number of refuse coals blended with the better grades and thus take advantage of a wide range of inferior coals available to his plant. Most interesting is his burning of mine dust directly in the furnace without previous preparation.

There are undoubtedly many other plants where a similar procedure might be employed to advantage; but each represents an individual problem, and the change should be made only after exhaustive investigation and with full consideration to the possible effect on availability at a time when ability to meet demand is paramount.

The Mercury-Vapor Cycle

The long-awaited information on the mercury-vapor installation at Kearny Station has been made available by Messrs. Smith and Thompson in their recent paper before the Metropolitan Section of the A.S.M.E. In addition, this comprehensive paper reviews the history of the mercury-vapor cycle to date and reveals the vast amount of research and development that has gone into making this form of binary cycle applicable on a large scale. It has been over eighteen years since the pioneer installation at Hartford served to confirm the possibilities of the mercury-vapor cycle and the intervening years have been productive of much practical knowledge concerning it. Both manufacturer and users are to be congratulated on their perseverence in carrying through the idea.

Test results at Kearny show a thermal performance somewhat better than the best thus far reported for the steam cycle; but, of course, heat rate is only one of several factors to be considered in any commercial application. That the paper made no reference to initial costs at either the Kearny or the Schenectady installations is not surprising, as much development work of a necessarily expensive nature was involved, and such cost figures would have therefore meant little. It would have been enlightening, however, had the authors given some indication of the probable initial unit cost of a subsequent comparable installation. Such figures, in conjunction with thermal performance, would form a basis for comparison with a plant operating wholly on the steam cycle.

Discussion at the meeting brought out that a mercury-vapor installation is best suited to topping service and base load operation; that the starting-up period is rather long; and that close attention must be given to mercury conditioning. It was further suggested that industries requiring steam for process work would find in the mercury plant an economical means of supplying the steam, with greater amounts of by-product power available than could be supplied by any other power cycle.

The St. Lawrence Agreement

St. Lawrence power advanced a step nearer actuality on March 21 when the President transmitted to Congress the text of the agreement with Canada concerning the seaway-power project. It is anticipated that Congress will be asked to approve this agreement by concurrent resolution which requires only a majority vote in contrast with a two-thirds vote of the Senate as is necessary for the ratification of a formal treaty. The agreement stipulates that the project shall be completed not later than December 31, 1948; yet it is being urged under the guise of a defense measure.

Preliminary estimates place the cost at 266 million dollars for the development in the International Section of the St. Lawrence of which Canada's contribution would be 60 million and New York State would be expected to pay 90 million toward the power part of the project. It is claimed by many that these estimates are too low and that the development is likely to cost nearer half a billion dollars before it is completed. If the supplementary appropriations that have been made for TVA are to be taken as a criterion, this latter view is probably closer to the total ultimate cost.

Provision is also made in the agreement for an additional diversion of five thousand cubic feet of water per second at Niagara Falls, by Canada and by the United States. This clause is timely and would make immediately available approximately 400,000 additional horsepower in plants already constructed with practically no additional expenditure.

Aside from the controversial navigation aspects involved and the fact that power developed at the International Section of the St. Lawrence could not be made available in time to be a factor in meeting defense needs, it is further argued that it would create a large demand on labor and materials at a time when they are needed in legitimate defense work.

Dresser Station Adds 50,000 Kw

By H. E. MATSON

Efficiency Engineer, Dresser Generating Station, Public Service Co. of Indiana

This 650-lb, 910-F addition is adjacent to the original station, which is a mine-mouth plant, and contains one 50,000-kw condensing turbine-generator supplied with steam by two three-drum 250,000-lb per hr, pulverized-coal-fired boilers equipped with continuous slag-drip furnaces tangentially fired. Economizers and air preheaters are provided. The installation is described and the predicted performance given.

DUE to the rapid growth in power demand in central, southern and western Indiana, it became apparent in 1939 that it would be necessary for the Public Service Company of Indiana to increase its generating capacity. Accordingly, Dresser Station, one of the company's two major generating plants, situated on the Wabash River about nine miles south of Terre Haute and with a capacity of 75,000 kw, was chosen as the logical location for the additional capacity. Plans were initiated by the Dresser Power Corporation, a wholly owned subsidiary of the Public Service Company of Indiana, with Sargent & Lundy, Inc., of Chicago as consulting engineers, for the erection of a new 50,000-kw addition immediately adjacent to the existing Dresser Station. This addition, which is now nearing completion, will be operated as a separate plant due to the impracticability of completely joining the heat balance of the original plant to the higher pressures and temperatures of the new plant. Operating steam conditions are 650 lb and 910 F, compared with 350 lb and 650 F for the original station. A cross-section of the new plant is shown in Fig. 1.

In the construction of the new building, the architectural lines of the old plant were followed, even to the height of the stacks (see photograph on cover). The new equipment of similar nature to the original installation was placed on like elevations so that ease of operating the two plants in conjunction was simplified. A new outdoor substation was constructed adjacent to the present substation. An additional feature is the steam cross-connection between the new and old plants whereby any steam generated by the new boilers in excess of that required for the new turbine-generator may be utilized in the old plant through a pressure-reducing and desuperheating station.

Heat Balance

The heat balance as shown in Fig. 2 is based on a load of 50,000 kw at the pressure and temperature indicated above and using 5th Vein, Indiana coal having the following proximate analysis, as received:

Moisture, per cent	11.00
Volatile, per cent	36.00
Fixed carbon, per cent	38.00
Ash, per cent	15.00
	100.00
Sulphur, per cent	3.5
Btu per lb	10,600
Ash-fusion temperature, F	2100

Steam is extracted from the 5th, 8th, 11th and 14th stages of the turbine for feedwater heating and for evaporator service. The extraction heaters are indicated as *A*, *B*, *D* and *E* (Fig. 2). The evaporator condenser is shown as *C*. Condensate is pumped from the hotwell through the air ejector and then to the heaters and evaporator condenser. The boiler-feed pumps are located, in the water cycle, between the evaporator-condenser and *D* heater. Bypassing of the heaters is also provided. Expected or predicted performance is as follows:

Load on turbine, kw	50,000
Water rate to throttle, lb per kwhr	8.572
Btu per kwhr to turbine	9626
Overall boiler efficiency, per cent	86.0
Btu per kwhr generated	11,200
Btu per kwhr to auxiliaries	600
Btu per kwhr output	11,800

With an operating efficiency ratio of 98 per cent, the Btu per kilowatt-hour sent out should be 12,030 and the plant thermal efficiency 28.4 per cent.

Steam-Generating Unit

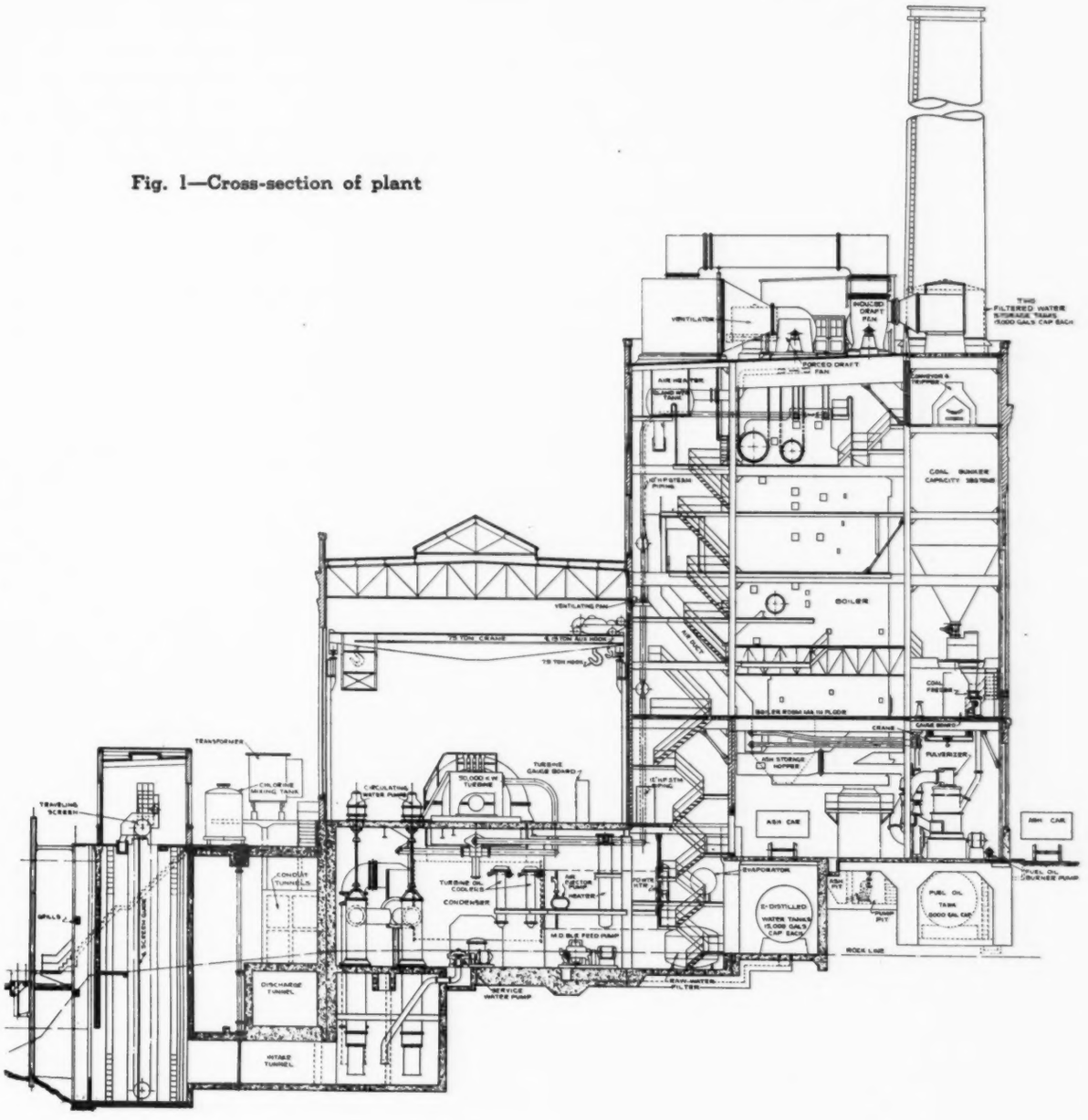
A cross-section of one of the two boilers is shown in Fig. 3. They are of the three-drum, bent-tube type, each rated at a normal continuous evaporation of 250,000

lb of steam per hr at 650 lb per sq in., and 910 F. The furnaces are entirely water-cooled. The water-wall tubes are of bifurcated construction so that the space between adjacent tubes is practically negligible, and the casing is constructed with a backing plate on the wall tubes, slabs of insulation and the outside steel casing.

water, the steam passes through heavy wire screens which aid in reducing the moisture content.

The heat release when operating at an output of 250,000 lb per hr will approximate 24,000 Btu per cu ft of furnace volume, and the boiler efficiency is expected to reach 87 per cent or better.

Fig. 1—Cross-section of plant



The superheater is designed so that the temperature will be maintained as nearly as possible at 910 F by means of regulating dampers, between steaming rates of 187,000 and 250,000 lb per hr with feedwater at 375 F.

The upper rear 60-in. drum is equipped with a bubble-type steam washer and perforations below the water line in the hooded steam baffle discharge all the steam through the feedwater. After passing through the feed-

The 9000-sq ft superheater in each unit is of the welded-joint type, specially developed for high temperatures and pressures. Tube elements are connected by welded joints to the headers.

A 3780-sq ft economizer, employing the staggered-tube arrangement, is located in the last pass of each boiler. The top and bottom rows of tubes are connected into seamless-steel headers through welded joints; also, the

upper and the lower bank of elements are connected through welded joints.

The air preheaters are of the tubular type, fully encased and arranged for three full passes of air across the tubes and counter flow. The elements are 43 ft long and have a total heating surface of 42,200 sq ft per unit.

Observation doors are provided on all parts of the furnace for a close check of performances on all sections of the unit. Facilities for hand lancing of possible slag deposits are provided on top of the boiler. See Fig. 4 for curves on performance.

Boiler Auxiliaries

Each boiler is equipped with one 85,000-cfm forced-draft fan and one 148,000-cfm induced-draft fan driven by constant-speed motors. Automatic vane control on the fans is provided.

Two bowl-type mills, each of 20,300 lb per hr nominal capacity, serve each boiler. These have integral exhausters and are fully equipped with feed-control mechanisms, fineness regulator and flexible couplings for direct-connected drive. The feeders are not integral with the mills but are located on the operating floor (see Fig. 1) and connected by pipes to the mills in the boiler-room basement.

The unit system is used with tangential or corner firing, each mill feeding to burners in the four corners. The burners are provided with adjustable air dampers and oil-fired lighting torches which are ignited from controls on the boiler panel.

Two motor-driven boiler-feed pumps and one steam-driven boiler-feed pump supply the boilers. Each of these pumps is of sufficient capacity to more than take care of one boiler with the steam-driven pumps held in reserve for emergency service.

Slag Disposal

The furnace bottoms are of the continuous slag-drip type with the slag dripping into a tank of water where it is shattered and dispersed. Periodically, the slag is sluiced from the tank over screens to a pump pit, and pumped from there to an overhead hopper which can be discharged into a standard railroad car. This arrangement for handling the quenched slag was necessary to tie in with a similar arrangement for cinder disposal in the old station. The dust is transported from the dust hoppers on the gas-discharge ducts by means of a vacuum system employing a hydrovactor. The unit will discharge into the slag-dewatering storage bin leaving commercially dry ash along with the slag to be dumped in cars.

Each boiler is provided with six automatic-valved revolving soot-blower units and five retractable soot-blower units. The economizer soot-blowing system consists of twelve of the automatic-valved type. All are designed for 775 lb operating pressure and saturated steam. There are no soot-blower units at the air preheater.

Turbine-Generator

The turbine-generator is a 50,000-kw, 85-per cent power factor, 3-phase, 60-cycle, 13,800-volt, 1800-rpm condensing unit with direct-connected exciter and pilot exciter. The turbine is designed for the steam condi-

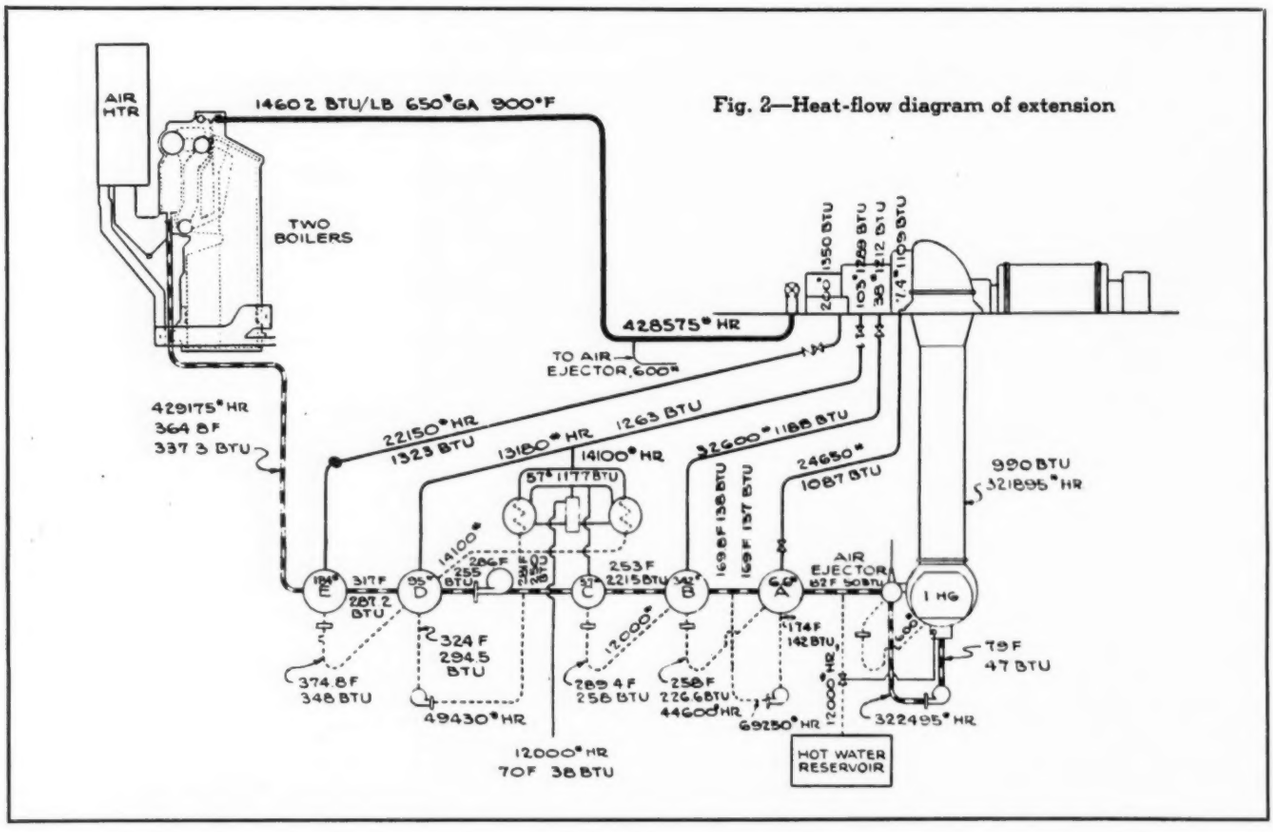


Fig. 2—Heat-flow diagram of extension

tions previously mentioned and the generator is air-cooled through a 17,560-sq ft surface air cooler. The turbine buckets are all of highly polished stainless steel. A motor-driven turning gear is located on the middle bearing cap and will rotate the turbine and generator rotor through a reduction gear at about 2 rpm. The curve for operating steam rate per kilowatt-hour indicates a fairly flat characteristic over a wide load range, especially after reaching the 20,000-kw point.

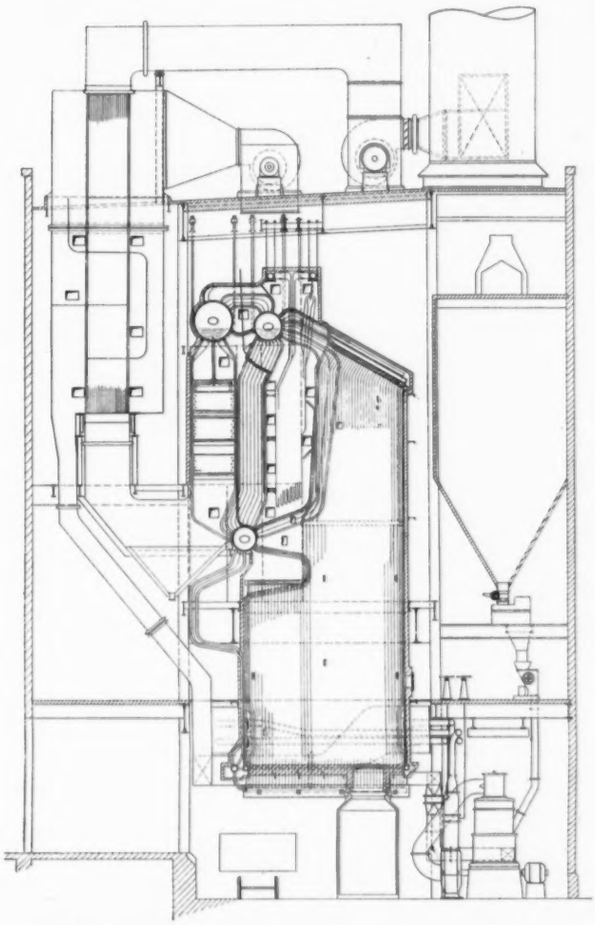


Fig. 3—Cross-section through steam-generating unit

The condenser is a two-pass, horizontal type, with 40,800 sq ft of effective cooling surface. Two vertical, submerged-type circulating water pumps furnish 48,000 gpm. The condenser tubes are of arsenical copper, rolled at both ends in Muntz-metal tube plates and the shell is of copper-bearing welded-steel plate with cast-iron water boxes. Since the station will operate under a closed feedwater cycle, a deaerating hotwell of 2500 gal capacity is installed to take care of hotwell makeup from external sources. Float controls on the hotwell provide for condensate overflow and normal or emergency makeup from a distilled-water storage tank.

A separate crib house and inlet on the river bank brings the circulating water through heavy stationary grizzlies and revolving screens to the intake tunnel where it is chlorinated for elimination of algae growth in the condenser tubes. The chlorinating equipment was designed by the engineering personnel at the plant.

As mentioned before, one of the features of the new plant is the installation of equipment to take steam from the new boiler plant for use in the old station at the correct pressure and temperature. The amount of steam available for this will vary, depending on load conditions impressed on the new No. 4 unit. Maximum steam flow through the pressure-reducing and desuperheating equipment is 250,000 lb per hr. The desuperheater will be of the steam-atomizing type. Pressure and temperature are controlled automatically or manually from a control panel. To insure a return to the new plant of an amount of water from the old plant equal to the steam received, a flow-balance control system is incorporated with this system when the new unit is in service. Return water is regulated by the new boiler-feed pump suction pressure when the new unit is not in service.

Coal Handling

The Dresser Generating Station is one of the few mouth-of-mine plants in the country. Coal is loaded on mine cars in the mine, hoisted to the tipple top, dumped over screens to a breaker which discharges

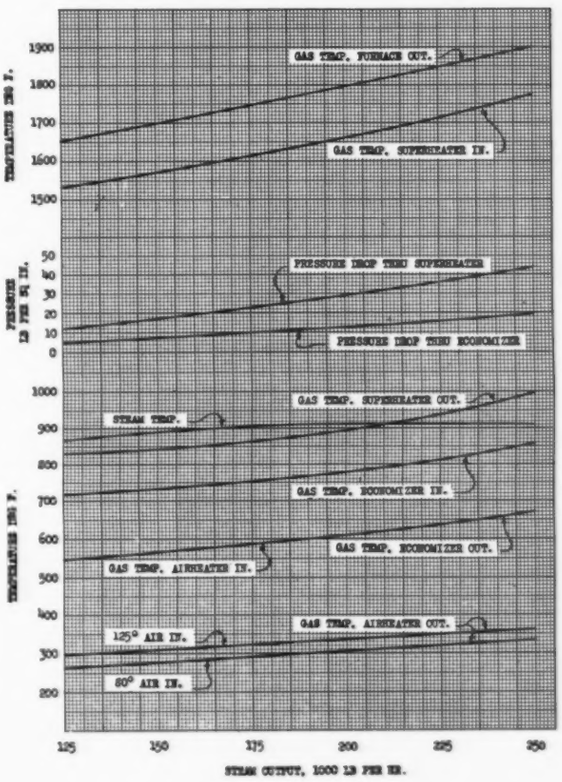


Fig. 4—Anticipated performance

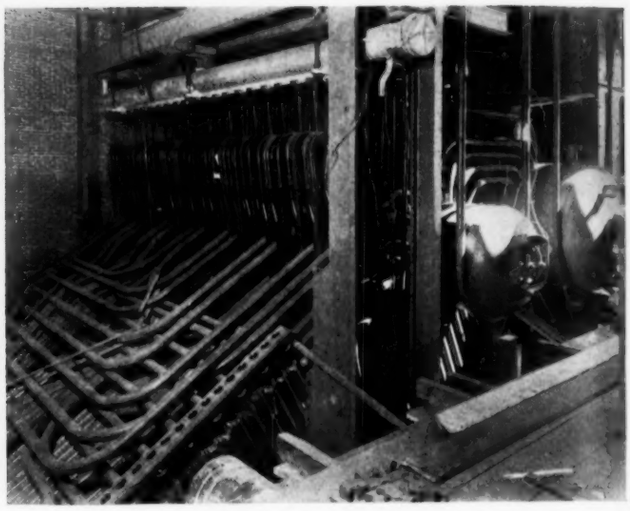
$1^1/_2$-in. size coal to a conveyor belt, weighed on a weightometer and carried to the present 2000-ton overhead bunkers in the plant. Magnetic pulleys are provided for separation of tramp iron, etc., and a special chute diverts coal to a 36-in. conveyor over the new 800-ton bunkers. The coal is weighed by automatic Richardson scales to each individual mill feeder.

Instrument and Controls

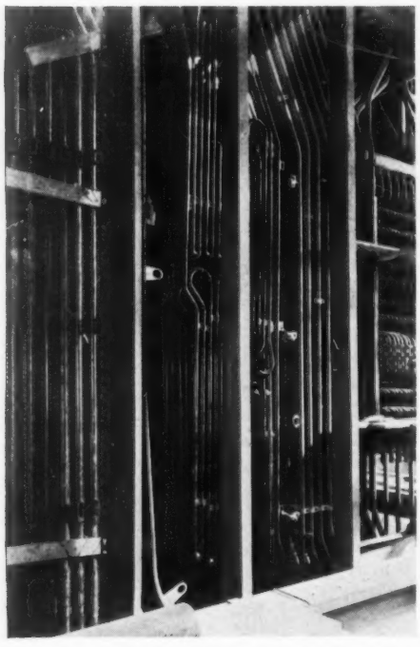
The boilers are equipped with full automatic regulators to control fuel and air supply for combustion, the

Construction Views of Dresser Steam Generating Unit

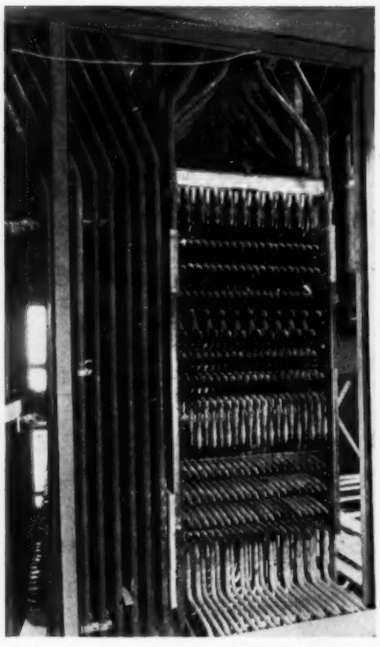
Inside of furnace looking up



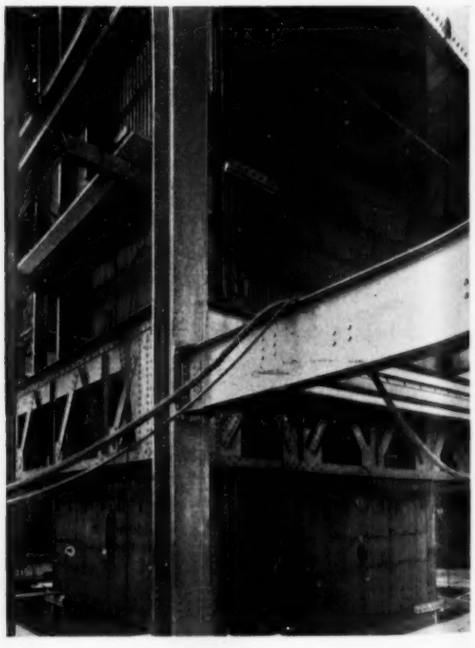
Upper part of unit showing drums, superheater header and supports, and furnace roof



Superheater elements, with fin-tube furnace wall on left and economizer on right



End view of economizer



Exterior of unit before installing casing

feedwater supply and the cross-over steam connection to the old plant. Steam temperature control at the superheater outlet is from the boiler panels but is not automatic. In the operation of the automatic controls a master controller transforms a measurement of steam pressure change to a master loading pressure. This is transmitted to the various regulators to cause them to make the necessary adjustments to correct the change in steam pressure. The two boiler control panels are arranged in a V-shape at the center front of the boilers so that operating conditions are apparent at a glance across the two panels.

Installation of temperature recorders is divided between the gas-filled bulb type and the potentiometer pyrometers. A complete installation of pressure gages, flowmeters, draft gages, conductivity recorders, CO_2 recorders, etc., is provided.

Water Conditioning

All water is taken from the Wabash River and properly conditioned before use in the boilers. The raw water is fed to an accelator tank which is complete with chemical feed and proportioning apparatus, pump-suction surge tank and float-control valves. This apparatus is designed to remove the largest portion of the raw water turbidity before being pumped to the filters. After passing through the filters the water is suitable for station service use and evaporator feed. The small amount of makeup to the condensate system is handled by the two evaporators. Further chemical treatment of water, when found to be necessary, will be made internally in the boiler drum. Complete provisions are made for water and steam sampling at pertinent points for checks and analyses.

Partial List of Equipment 1941 Addition—Dresser Generating Station

Boiler Equipment

Boilers
Two, three-drum, bent-tube type, operating pressure 650 lb, steam temperature 910 F, capacity 250,000 lb per hr, tangential firing, continuous slag discharge.—*Combustion Engineering Company, Inc.*

Superheaters
"Elesco," convection type, 9000 sq ft heating surface, steam temperature bypass damper control.—*Combustion Engineering Company, Inc.*

Furnaces
Water-cooled, 13,580 cu ft, volume, 4840 sq ft heating surface per boiler—*Combustion Engineering Company, Inc.*

Pulverizers
Two per boiler, C.E.-Raymond bowl type, integral exhauster, 10 tons per hr capacity each.—*Combustion Engineering Company, Inc.*

Burners
Eight per boiler, two per corner arranged for oil lighting off.—*Combustion Engineering Company, Inc.*

Economizers
"Elesco" fin-tube, horizontal bare-tube, counter flow, 3780 sq ft heating surface.—*Combustion Engineering Company, Inc.*

Air Preheaters
Tubular type, vertical, 42,200 sq ft heating surface.—*Combustion Engineering Company, Inc.*

Forced-Draft Fans
One per boiler, 85,000 cfm, 12.5 in. static pressure at 1180 rpm, constant speed type, driven by 250-hp *Westinghouse* motor.—*B. F. Sturtevant Company.*

Induced-Draft Fans
One per boiler, 148,000 cfm, 14.0 in. static pressure at 1180 rpm, constant-speed type, driven by 600-hp *Westinghouse* motor.—*B. F. Sturtevant Company.*

Feedwater Regulators
One 5-in., drum-level control per boiler, hydraulic operated Smoot type.—*Republic Flow Meters Company.*

Soot Blowers
Twenty-three per boiler, eighteen revolving type, five retractable type.—*Diamond Power Specialty Company.*

Turbine Equipment

Turbine-Generator
One 17-stage, 50,000-kw, 85-per cent power factor, 58,824-kva, 3-phase, 60-cycle, 13,800-volt, 1800-rpm, condensing unit with direct-connected exciter and pilot exciter. Designed for 650 lb and 910 F.—*General Electric Company.*

Air Cooler
Four sections, arsenical copper tubes, 17,560 sq ft cooling surface.—*General Electric Company.*

Turbine Exhaust Joint
Phillips expansion joint.

Condenser
One, horizontal, 2-pass, 335,000 lb per hr capacity, 48,000 gal per min cooling water, arsenical copper tubes rolled in Muntz metal tube plates, cooling surface 40,800 sq ft.—*Worthington Pump and Machinery Corporation.*

Condensate Pumps
Two, horizontal, 4-stage, 900-gpm capacity, 200-hp motor-driven.—*Worthington Pump and Machinery Corp.*

Circulating Water Pumps
Two vertical, 36-in., 24,000-gpm capacity, 250 hp motor-driven. *Worthington Pump and Machinery Corporation.*

Feedwater Heating Equipment

Extraction Heaters
Two low-pressure heaters, 1582 sq ft and 1362 sq ft heating surface; two high-pressure heaters, 1034 sq ft heating surface each. All are vertical floating head with arsenical copper tubes.—*Griscom-Russell Company.*

Evaporator Condenser
One, vertical floating head, 682 sq ft heating surface, arsenical copper tubes.—*Griscom-Russell Company.*

Evaporators
Two, horizontal, submerged type, single-effect parallel, 200 sq ft heating surface, arsenical copper tubes.—*Griscom-Russell Company.*

Evaporator Deaerator
Elliott Company.

Heater Drain Pumps
Three, horizontal, two stage.—*Worthington Pump and Machinery Corporation.*

Boiler Feed Pumps
Two motor-driven and one turbine-driven, horizontal, 6-stage split-casing, 760 gpm capacity, 900 lb discharge pressure, 3550 rpm.—*Worthington Pump and Machinery Corporation.*

Instruments and Gages

Steam Flowmeters
Bailey Meter Company

Water Flowmeters
Leeds & Northrup Company
Builders Iron Foundry Company
Republic Flowmeter Company

Pressure Gages
Consolidated-Ashcroft-Hancock Company
The Foxboro Company

Draft Gages
The Hays Corporation

Temperature Recorders
The Foxboro Company
Leeds & Northrup Company
Republic Flowmeter Company

Conductivity Recorders
Leeds & Northrup Company

Thermometers
The Taylor Instrument Company

Combustion Control Equipment
Republic Flowmeter Company (Smoot)

Major Electrical Equipment (Power Station)

15-Kv oil circuit-breakers
Westinghouse Electric & Mfg. Company.
Field circuit-breakers and cubicles
Westinghouse Electric & Mfg. Company.
5000-volt metal-clad switch gear
Westinghouse Electric & Mfg. Company.
600-volt metal-clad switch gear
Westinghouse Electric & Mfg. Company.
Auxiliary power transformer
2—5000 kva (1 main and 1 reserve), 3-phase, 13,200/2400/480 volts—*Westinghouse Elec. & Mfg. Company.*
175-Kw reserve exciter set
General Electric Company.
Control benchboard
General Electric Company.

Major Electrical Equipment (132 KV Sub-station)

One—132-kv oil circuit-breaker
Westinghouse Electric & Mfg. Company.
Two—138,000/115-volt potential transformer
Westinghouse Electric & Mfg. Company.
Four—16,667-kva (1 spare) single-phase, main power transformers, 79,600/13,200 to give 138,000 volts star-connected.—*Westinghouse Electric & Mfg. Company.*
Six—115,000-volt disconnecting switches
Delta-Star Electric Company.

The Mercury-Vapor Process

By A. R. SMITH and E. S. THOMPSON
Turbine Engineering Department
General Electric Company

Excerpts from a paper presented before the Metropolitan Section, A.S.M.E., on March 19, 1941, in which the authors review the development work in the mercury-vapor boiler and turbine from its inception in 1912 to the latest unit installed at the Kearny Station in 1940, which is described and test results given.

IN THIS process mercury is vaporized in a boiler at comparatively low pressure and passes through a mercury turbine which drives a generator. The vapor from the turbine is exhausted to a condenser boiler where its latent heat is transferred to water, which vaporizes at any desired pressure. The steam formed in the condenser boiler is superheated in coils located in the gas passages of the mercury boiler and is then used in a steam turbine or for process. Fig. 1 is a diagram of the arrangement.

The efficiency of a power cycle is generally determined by the temperature range through which it operates; the greater the temperature range, the higher the efficiency. The lower temperature limit is rather definitely set by the cooling medium available. To improve the efficiency it is necessary to increase the initial temperature to the limit allowable by the materials available. It makes considerable difference, however, whether the high temperature is obtained by increasing the pressure or by superheating the vapor. The energy required to superheat vapor to a certain temperature is only a fraction of that necessary to obtain the same temperature by increasing the pressure and maintaining the vapor in a dry and saturated state.

Steam is the best medium available for use as the lower-temperature fluid in a binary cycle. Certain other fluids such as ammonia, methyl chloride, ethyl chloride, sodium dioxide and ethyl bromide have been investigated but no commercial success has yet been obtained.

Mercury has many advantages as a thermodynamic fluid for use in power generation. Its vapor pressure is low at high temperatures, being 140 lb per sq in. gage at 975 F and 300 lb per sq in. at 1100 F. Mercury is an element and is stable at temperatures well above the limit imposed by materials now available for boiler tubes, piping and turbine nozzles. Its critical temperature is about 2240 F. There is no danger of solidifying in the tubes, for the freezing point is −37.97 F.

Very little power is required to maintain vacuum in the condenser boiler because air leakage is very low and the absolute pressure relatively high. With a 25 F terminal difference a mercury pressure of 6.07 lb per sq in. abs will produce 1200 lb abs steam, and a mercury condenser pressure of 1.20 lb per sq in. abs will produce 400 lb abs steam.

The specific heat of the liquid is only one-thirtieth that of water at 80 F and one-sixty-sixth that of water at 650 F. This means a steep liquid line on the temperature-entropy diagram, so that nearly ideal conditions are inherent in the cycle and no regenerative feed heating is required.

Early Developments

The mercury-vapor process was introduced by Dr. W. LeR. Emmet in a paper before the American Institute of Electrical Engineers, December 16, 1913, and the first experimental boiler consisted of a single tube containing a solid core with a small clearance between the core and the tube. A central hole in the core provided the downward circulation of the liquid. Some of the fundamental requirements for mercury boilers were discovered with this apparatus, but many years were to pass before a way was found to make mercury wet the tube surface, thereby increasing the heat-transfer rate with lower circulation ratios.

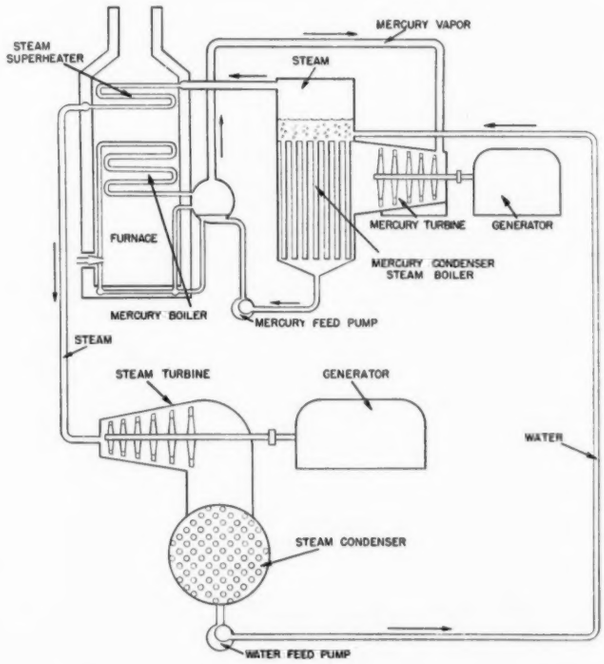


Fig. 1—Diagram of mercury-vapor-steam system

Several boilers of various capacities were built and tested at Schenectady and one of these units successfully produced 1000 kw from the mercury-turbine generator.

Hartford Installation

The first commercial installation was at the Dutch Point Station of the Hartford Electric Light Company in 1922. This was designed to deliver 1800 kw from the mercury turbine and to produce 40,000 lb of steam per hour at 200 lb gage and 100 F superheat. The boiler employed the fire-tube principle and operated at 35 lb gage mercury pressure.

Inadequate provision for expansion of adjacent tubes and inaccessibility for cleaning made it necessary to replace this boiler in 1925 with one made up of suspended

TABLE 1—PERFORMANCE RECORD OF 10,000-KW MERCURY PLANT AT SOUTH MEADOW STATION, HARTFORD

Year	Kwhr Mercury Only at Approximately 4000 Btu	Kwhr total Mercury and Steam (Net)	Btu per Kwhr	Hours Run
1928	2,900,000	5,700,000	....	429
1929	5,600,000	11,700,000	11,200	993
1930	52,500,000	121,000,000	10,300	6157
1931	5,400,000	12,700,000	11,300	651
1932	49,400,000	110,000,000	10,600	6516
1933	43,000.000	102,000,000	10,500	6753
1934	51,773,000	124,283,533	10,889	7596
1935	49,190,000	122,096,850	10,250	7212
1936	52,725,000	129,261,710	10,210	7309
1937	49,979,000	125,737,275	10,120	7729
1938	47,646,000	123,023,058	10,000	7684
1939	50,240,000	131,122,000	10,000	8140
(1940 to 9-25-40)	27,712,000	74,897,000	10,250	5162
Total	488,065,000	1,193,521,426		72,331

"porcupine" tubes, there being four headers each with 160 such tubes. Short coils were provided above the headers to function as mercury superheater elements. The operating pressure was 70 lb gage. The turbine and the condenser boiler were placed above the mercury boiler to permit the condensed mercury to flow back by gravity through the sump and liquid heater to the boiler drum.

The mercury unit now operating at South Meadow Station was installed in 1928. The mercury boiler, which operates at 85 lb gage pressure and 908 F mercury temperature, has seven 37-in. drums from each of which project 440 porcupine tubes $5^1/_2$ ft long and $3^1/_8$ in. outside diameter. The 10,000-kw mercury turbine has five impulse stages and the two condenser boilers supply steam to the superheater from which it is delivered at 375 lb pressure and 700 F to the station mains. The performance of this unit is given in Table 1.

Schenectady Installation

In 1932 two 20,000-kw installations were begun, one at the Schenectady Works of the General Electric Company and the other at the Kearny Station of the Public Service Electric and Gas Company of New Jersey, each designed for 140 lb gage mercury-boiler pressure and 975 F. The Schenectady plant differed from all previous plants in that the mercury turbine-generator and condenser boilers were not placed above the mercury boiler, the condensed mercury liquid being returned to the boiler by means of a centrifugal pump.

Fig. 2 is a section through the Schenectady mercury boiler which has seven drums and the same type of porcupine tubes as the Hartford boiler, but much better utilization of the radiant heat by lining the upper furnace walls with mercury vaporizing surface and the lower part of the furnace walls with steaming tubes. The mercury wall tubes were made by embedding three tubes in copper in a frame to obtain more uniform heat transfer around the periphery of each tube. The feed for these wall-tube sections is obtained from outside downcomers at each end of each drum. The water walls function as a 400-lb steam boiler with the steam drums located on each side, exterior to the furnace.

The turbine unit is a five-stage, 900-rpm machine rated at 20,000 kw. Mercury vapor enters the center annular chamber and flows in both directions to the exhaust openings and to the two condenser boilers. Projection of the shaft through the turbine casing is in the vacuum space so two packings to prevent leakage of air into the condensers are used but no high-pressure packing is required.

The total steam output from the condenser boilers and from the water walls is superheated and then is added to the output of a steam boiler and flows at 450

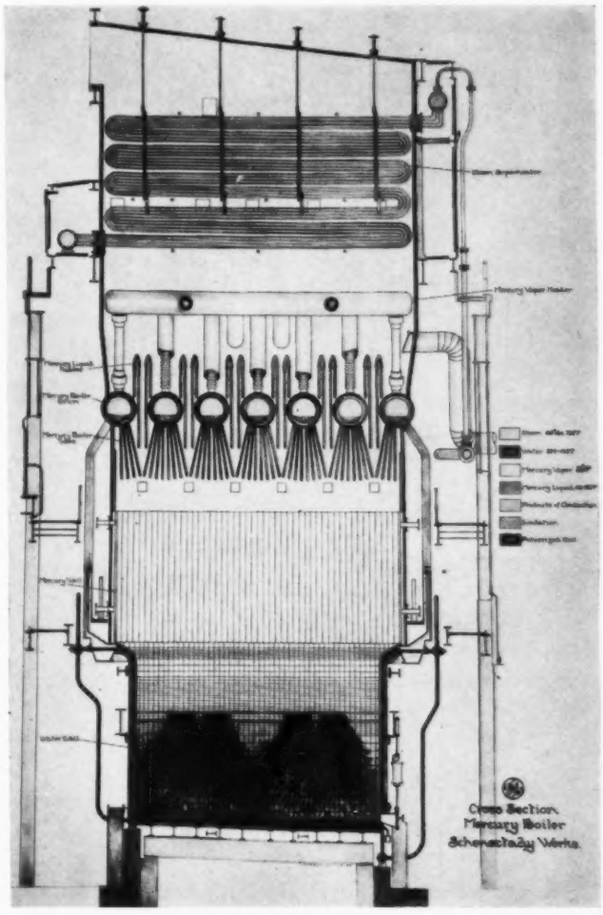


Fig. 2—Cross-section of mercury boiler at Schenectady

lb gage, 750 F to a 6000-kw, 3600-rpm back-pressure steam turbine, the exhaust from which, at 225 lb, 647 F, supplies industrial process steam at the Schenectady Works.

This installation, with the exception of the control panels, firing aisles, pumps and pulverizers, is installed outside and has passed through several severe winters without any operating difficulties.

The original mercury plant installed at Kearny Station was first operated in March 1933. The boiler, turbine-generator and condenser boilers were duplicates of those at Schenectady, except that the mercury-boiler feed is returned by gravity as at Hartford. The first boiler was operated until September 1938, when it was removed to make way for a new one of advanced design, which will be described later.

Forced-Circulation Boiler

An interesting development was a 1000-kw forced-circulation boiler unit which was tested at Schenectady. The firebox was formed of helically wound tubes forming a cylindrical combustion chamber. For a short distance above the bottom of the firebox the tubes were open-spaced to allow the gas to pass out and up through a concentric mercury-liquid heater and steam superheater. After leaving the steam superheater the gas passed through a two-pass air preheater to the stack.

Mercury liquid was pumped into a distributing chamber at the bottom of the boiler and then through the

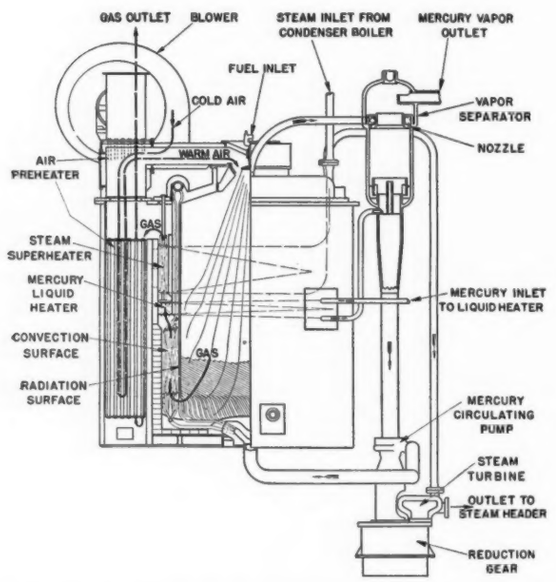


Fig. 3—Forced-circulation mercury boiler supplying 1900-kw turbine

radiation tubes to a ring header at the top which discharged to the separator. The separator contained nozzles in which the vapor was formed by flashing due to the release of pressure. To prevent any evaporation in the boiler surfaces a circulation ratio of 35 to 1 was maintained.

Test data and experience gained from this unit led to the design of the forced-circulation boiler installed at the River Works of the Company at Lynn, Mass., in 1937. This is shown in Fig. 3. It delivers sufficient mercury vapor at 165 lb gage, 1000 F to produce 1000 kw in the mercury turbine-generator and 12,650 lb of steam at 180 lb gage, 150 deg F superheat. The design was such that the elements could be completely assembled in the factory, thus requiring a minimum of expense for field erection. After operating successfully for 6000 hr the installation was shut down in August 1939.

A small mercury boiler was installed at the Pittsfield Works of the General Electric Company in 1937 to study the action of a unit composed of relatively high vertical wall tubes with natural circulation. This unit produced 4,931,000 kwhr from the mercury turbine-generator and 82,000,000 lb of steam at 185 lb gage, 650 F during the test operation.

New Mercury Boiler at Kearny

This new boiler at Kearny Station began operation on May 5, 1940. It produces 20,000 kw from the mercury turbine-generator and 300,000 lb of steam per hour at 365 lb gage and 750 F. As shown in Fig. 4, the furnace is of octagonal shape for the purpose of conserving mercury and better to equalize the heat absorbed by all the furnace tubes. The burners are located on each of the eight sides and will burn either coal or oil.

The furnace walls are completely covered with mercury tubes, which are practically contiguous, having a minimum inside diameter of $^{13}/_{16}$ in. at the bottom and 1 in. at the top of the vertical run. At the beginning of the arch at the top of the vertical run the tubes are supported by hangers (see Fig. 5), so that they hang vertically and partially support the bottom which is formed as a unit with the structural-steel frame. Large coil springs on the underside aid in supporting the bottom. Expansion of the tubes downward at full load is $2^{13}/_{16}$ in.

The porcupine tubes used for many years were ingenious and functioned well, but the small passages were a potential source of plugging and they were hard to clean, as well as expensive to manufacture. Therefore, they were not employed in the new Kearny boiler. By substituting wall tubes for the porcupine tube surface it became possible to remove the complication of seven drums which involved equalizing difficulties and other disadvantageous features. The new boiler has a single drum of 54 in. inside diameter with $4^1/_2$-in. walls, 30 ft long and weighing 90,000 lb. Fig. 6 is a section through the drum showing the arrangement of baffles.

To form the slag screen, 288 of the furnace wall tubes are continued across the reduced section or neck of the furnace, being attached at one end to a movable panel and at the other end to the drum.

The convection surface consists of six bundles of tubes above the drum. They are individually supported by vertical water-cooled supports, and are spaced for accessibility and employment of soot blowers. These mercury convection tubes are $1^7/_8$ in. inside diameter in the lower bank and $2^1/_4$ in. inside diameter in the two upper banks. They are fed from 180 of the furnace wall tubes at the top of the upper bundles and at the top of the lower bundles. The middle bundles are in series with the upper bundles. During operation the thermal circulating action lifts the mixture of liquid and vapor to the top of the tube banks and from this point it flows back to the drum by means of a combination of pressure drop and gravity head. When the boiler is cold all the mercury in the convection bank drains back into the drum.

The steam superheater, located above the mercury convection tube banks, is of conventional design and the air preheater is of the single-pass tubular type.

The Kearny boiler contains 392,000 lb of mercury, sufficient to generate 20,000 kw per hr in the mercury turbine and 30,000 kw from the steam generated in the condenser boiler. Since auxiliary equipment requires 1200 kw, the total mercury in the boiler amounts to 8 lb per net kilowatt capacity.

The design of this boiler, in so far as the functioning of the mercury is concerned, was by the General Electric Company. The mechanical design, combustion facilities and erection were done by Babcock & Wilcox Company.

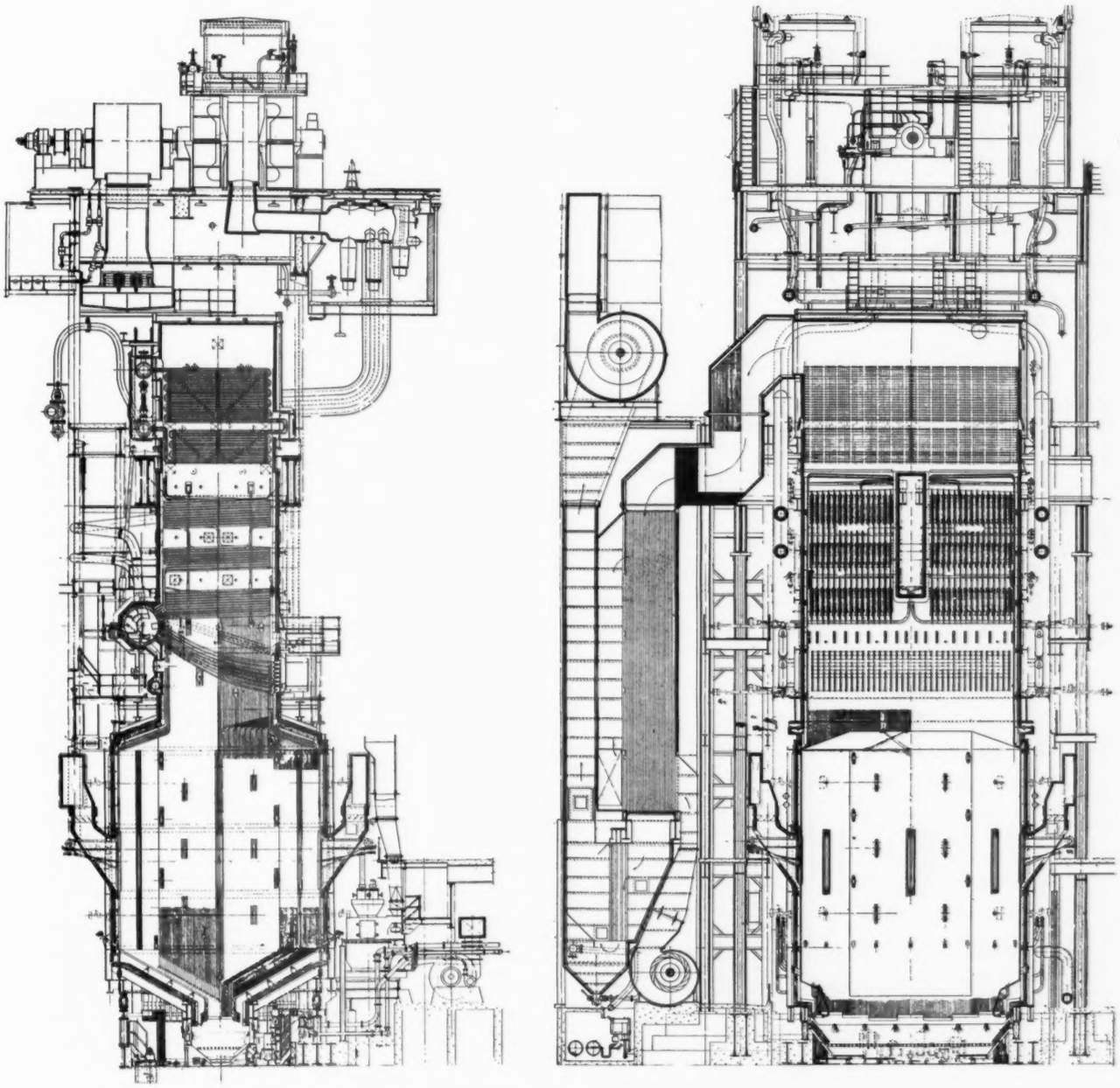


Fig. 4—Vertical sections through new mercury boiler at Kearny

The mercury turbine, which is of the double-flow, five-stage type, is rated at 2000 kw, 900 rpm, and is in excellent condition after five years of actual service. Fig. 7 shows one of the shaft packings which prevent air leakage into the turbine. It is a liquid-seal packing in which the seal is maintained by mercury liquid being whirled by the rotating cup which is part of the shaft sleeve. Mercury overflowing from the cup, as well as mercury from the inner casing, drains by gravity to a cooler, in which the cooling is done by a water-filled coil, and is then drawn back into the rotating cup by the vacuum on the condenser side of the seal. A drain to the condenser ahead of the outside carbon packing ring prevents any escape of mercury. Neutral gas is supplied to the middle carbon ring box and the excess, together with any air that leaks past the outside carbon ring, is sucked off to the stack from the outside packing box. The small amount of makeup liquid required is obtained from that which is condensed in the air-removal coolers on the condenser boilers.

An air-removal cooler is provided for each condenser boiler. The cooling coil passes all the feedwater enter-

ing the condenser boiler steam drum. Air and other noncondensable gases are drawn from the condenser shell into the air-removal cooler and then through a secondary cooler to the vacuum pump. Mercury condensed in the air-removal coolers is used as makeup for the shaft seal

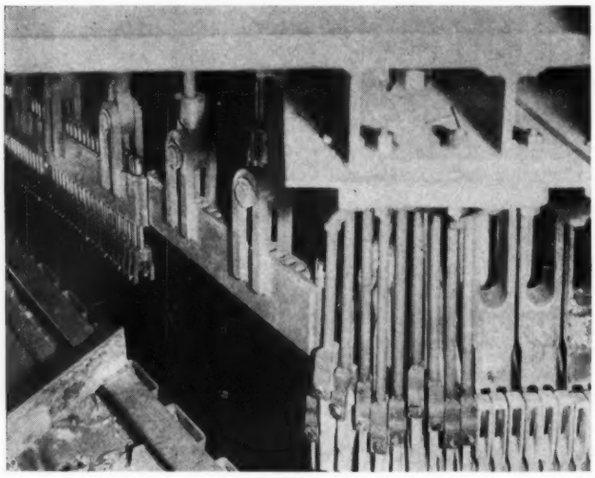


Fig. 5—Furnace-wall tube suspension at arch during construction of Kearny mercury boiler

packings and any excess is drained directly back to the condenser. Mercury condensed in the secondary cooler is drained to the sump.

Steam-jet air ejectors are used for rapidly reducing the pressure in the system before starting.

Boiler Filling and Draining System

A tank in the basement will store the 392,000 lb of mercury in the system if it becomes necessary to drain the boiler. In the event of a leak two emergency drain

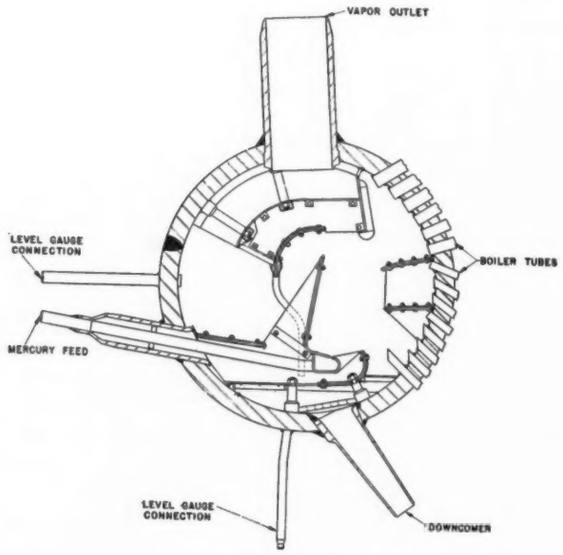


Fig. 6—Section through mercury boiler drum

valves can be opened which allow the mercury to rapidly drain through a cooler to the tank. A small pump in this tank will return the mercury to the boiler drum.

Mercury Detector

The first reliable mercury detector depended upon the action of mercury vapor on selenium-sulphide coated paper. Samples from the flues were continuously blown on a slowly rotating chart and the chart was scanned by a photoelectric cell which would actuate an alarm if the paper darkened due to the presence of mercury vapor in the gas. Selenium sulphide is extremely reactive toward mercury vapor, black compounds of mercury sulphide and mercury selenide being formed. This instrument can detect one part per million of mercury vapor in the flue gas.

The latest mercury detector is of the optical type and its operation depends upon the opacity of mercury vapor to ultra-violet light of a certain wave length.

Tube Material

Up to the time of the Lynn boiler which had chrome-molybdenum-steel tubes, all previous mercury boilers were made of ordinary low-carbon steel, and in most cases were calorized by the dip method and heat-treated. This was done before there was any knowledge of the

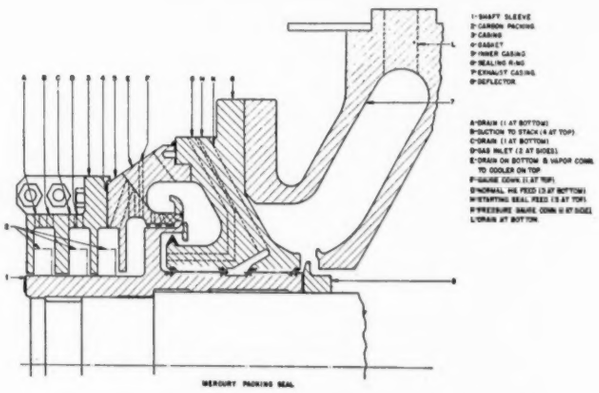


Fig. 7—Mercury packing seal on 20,000-kw turbine

rupture strength of such material at high temperature for extended periods of time. In 1937 test machines were started to study the long-time rupture strength under temperature of carbon steel and many kinds of alloy steels.

The results of these rupture tests, together with other considerations, led to the selection of an alloy called Sicromo 5S (formerly known as Sicromo 5) for the Kearny boiler tubes. This alloy contains 0.12 per cent carbon, 0.50 per cent molybdenum, 5.0 per cent chromium and 1.5 per cent silicon.

The particular composition selected for these tubes contains sufficient chromium and silicon to resist oxidation at the operating temperature and with the usual character of coal or oil ash. In the cooler passes of the boiler Croloy 3, used for the lower bundles of the fog bank, and Croloy 2, used for the upper bundles of the fog bank, will give equal protection.

Solubility of Iron in Mercury

The solubility of iron in mercury at high temperature has been a fundamental obstacle in the development of the mercury cycle. This action reduced the thickness

of the metal, and the disintegrated iron and iron oxide were deposited in some places on the heating surfaces in the lower-temperature regions, frequently restricting or stopping the flow of mercury or vapor.

How far this solubility is retarded by the use of Sicromo 5S steel can be seen from Table 2, which shows the rate of solubility per year expressed in mils. The

TABLE 2—SOLUBILITY OF STEEL IN MERCURY IN MILS PER YEAR

Temperature, Deg F	Carbon Steel	5 Per Cent Chrome	Sicromo No. 5S
900	4	2	0.2
1000	9	4	0.5
1100	22	10	1.1
1200	53	25	2.5

carbon steel is the material used in Hartford, Schenectady, Pittsfield and the old Kearny boilers. The 5 per cent chrome steel was used in Lynn. The new Kearny boiler and slag-screen tubes are made of Sicromo 5S.

Wetting and Dewetting

Steel surfaces, even though slightly oxidized, can be wetted by mercury alone with time and patience. But such surfaces will not remain wetted if more oxygen is introduced. As the result of a comprehensive search for suitable deoxidizing and wetting agents, the combination of magnesium and titanium has been found to hold the boiler tubes in a properly wetted condition unless the air infiltration is excessive. In combination with the titanium concentration previously mentioned it is necessary to maintain 0.002 per cent metal magnesium in solution in the boiler. It appears that magnesium is essential to maintain the titanium activity, and that titanium assists in wetting the steel.

Oxides

The formation of oxides formerly caused considerable trouble in the mercury cycle. These difficulties appeared as dewetting, causing poor heat transfer, and mercury-oxide and iron-oxide deposits in tubes, sumps and pipes. The possible sources of oxygen are air infiltration through the turbine and condenser casings operating below atmospheric pressure, the turbine shaft packings, air in the boiler when starting up and water leaks in the condenser boilers or coolers.

Excessive oxygen means loss of the titanium and magnesium and the production of solids. To prevent air leakage the new type of mercury shaft packing was developed, and the valve stems operating under vacuum were covered with metal caps. These precautions have reduced the air leakage at Kearny from 300 cu ft per hr to less than 0.4 cu ft.

With this slight amount of air which still infiltrates into the system it is relatively easy to absorb all the oxygen with the magnesium, forming magnesium oxide which is easily cleaned out.

When shutting down a plant, nitrogen is bled into the system until the temperature is so low that the rate of oxidation is negligible. When starting up a plant, it is pumped down to a reasonable vacuum before the fires are lighted.

Kearny Test Results

During the months of May and June 1940 tests of the mercury plant at Kearny were conducted. Eight-hour tests at 37½, 50, 62½, 75, 87½ and 100 per cent load were made, allowing at least 48 hr at each load before making the test. A test at 30 per cent load was run for two hours.

The results are shown in Table 3 and the net plant heat rate is shown in Fig. 8. The full load heat rate of 9175 Btu per kwhr, or 37.19 per cent thermal efficiency, means that a kilowatt-hour is being produced for 0.502 lb of 18,275 Btu per lb bunker C fuel oil.

The steam from the superheater was delivered to the station mains. As no particular steam turbine was driven by the steam produced in the mercury plant it was necessary to make a calculation of the total plant auxiliary power, which was deducted in order to arrive at a net plant heat rate. The equivalent power from the steam is based on the assumption that the steam made in the mercury plant was being used in modern steam turbines from which steam was extracted to heat the feedwater to the temperatures prevailing during the tests.

TABLE 3—TEST PERFORMANCE OF PRESENT KEARNY INSTALLATION

Test No.	1	2	3	4	5	6	7	8
Date, 1940	5–9	5–11	5–16	5–20	5–23	5–27	6–17	6–18
Mercury turbine generator output, kw	6250	7763	10188	12712	15333	17683	20213	20175
Steam flow, 1000 lb per hr	125.7	140.9	178.4	211.7	239.9	271.9	306.6	306.7
Steam pressure, lb per sq in. gage	351.6	355.6	355.4	356.6	356.8	359.7	358.1	359.4
Steam temperature, F	666	689	708	682	700	688	711	706
Feedwater temperature, F	375	306.7	375.3	374.2	370.7	367	374	374
Equivalent steam turbine output, kw	11863	13497	17290	20223	23141	26185	29790	29713
Total gross output, kw	18113	21260	27478	32935	38474	43868	50003	49888
Auxiliary power (calc.), kw	396	466	610	743	887	1034	1212	1208
Total net output, kw	17717	20794	26868	32192	37587	42834	48791	48680
Fuel oil, lb per hr	9481	11464	14346	16672	19029	21760	24626	24518
Stack temperature, F	310	368	369	370	358	373	382	374
Calorific value of fuel (as fired), Btu per lb	18276	18276	18276	18276	18272	18272	18268	18202
Net plant heat rate, Btu per kwhr	9780	10076	9758	9465	9250	9282	9220	9168
Net plant heat rate corrected to 370 F stack temperature, Btu per kwhr	9948	10082	9761	9465	9282	9274	9189	9158

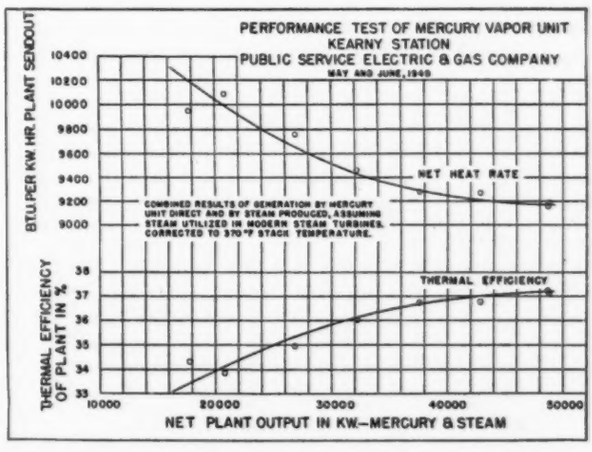


Fig. 8—Net plant heat rate and thermal efficiency of Kearny installation

This Was Not a Blind-Fold Test

● Not a Blind-fold Test, but a scientifically controlled *endurance test* was made on a Crosby gage and two competing gages to determine their relative stamina, dependability, and continued accuracy under gruelling service conditions.

A pumping device to reproduce operating conditions was especially designed and constructed to test the gages, the pulsating pressure thus produced causing the hands to deflect from zero to maximum graduation and back to zero, the cycle repeated more than 90 times a minute.

After 14 hours on test, the Bourdon tube in gage "A" ruptured; the Crosby gage maintained its guaranteed accuracy of ½ of 1%. After 83½ hours, the tube in gage "B" failed; the Crosby gage was still accurate to 1.2% of its maximum range. The test was continued on the Crosby gage for more than 375 hours, at which time there was no sign of tube failure.

The movements of the gages were next tested on a machine that moved the sector back and forth through the full arc.

After 17 hours, the movement from gage "B" broke down and jammed. The movement from gage "A" lasted 216 hours, when the teeth on the sector and pinion failed, stopping the test. The Crosby movement still showed no sign of wear. Even after 9,928 hours (more than *one billion* cycles) the Crosby movement continued to function and showed only slight signs of wear.

The tests described above on the Bourdon tubes and movements, the vital parts of a gage, demonstrate conclusively the ability of the Crosby gage to withstand pressure fluctuations, resist vibration, and to "take" punishment that destroyed other types of gages, and still give faithful service—a concrete example of the quality and economy of Crosby.

CROSBY STEAM GAGE AND VALVE CO.

BOSTON • NEW YORK • CHICAGO
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Trends in Steam Plant Development

A brief review of progress in the design of steam power-plant equipment to meet advances in steam conditions and operation, the influence on economy of generation and some indications of future trends judged by experience with present practice.

By A. G. CHRISTIE

Professor of Mechanical Engineering,

The Johns Hopkins University

A PROMINENT engineer in this country about 1910 stated in a discussion of the probable development of the steam turbine, that it was inconceivable that turbines would ever be needed of larger size than 25,000 kw. Considering subsequent developments, how ludicrous his statement reads. This incident must impress one with the fact that the prediction of future power-plant developments is a dangerous undertaking. Caution must therefore be exercised in judging the trends herein discussed.

Several years ago the desirability and economics of the standardization of steam-plant equipment was seriously considered and some steps were taken to achieve this end. But developments in the power industry have not ceased and at present there is little standardization in much of the principal equipment that goes into a large power house. Trends in steam-plant development, judged by recent practice, are influenced by the following factors:

(*a*) The increasing use of alloys capable of standing higher temperatures
(*b*) Higher temperatures which permit the use of higher pressures without reheating
(*c*) The design of larger turbines at 3600 rpm
(*d*) Tailor-made boilers and auxiliary equipment
(*e*) The introduction of forced-circulation boilers
(*f*) Improved station economy as a result of these changes
(*g*) The construction of more stations of moderate size
(*h*) Comparatively stationary total costs of production.

Alloys for High Temperatures

A study of a Mollier diagram indicates that more energy is made available from an increase of 100 deg F in temperature than from 100 lb gain in pressure in the higher pressure ranges. Hence, as high steam temperatures have been employed as available metals will stand. At the moment this temperature limit appears to be about 1000 F which has been fixed by the properties of commercial chrome molybdenum steels. Many turbines have been and are being built for temperatures of 900 to 960 F.

Research has been undertaken to find new materials with satisfactory properties at still higher temperatures. The introduction of the gas turbine as a power-generating unit and a realization of the gains to be attained with high temperatures on this unit, has acted as an incentive in the search for materials suitable for these conditions. Alloys containing columbium are said to offer much promise at higher temperatures. Undoubtedly, still other alloys will be found suitable for this purpose. Materials permitting the use of 1200 F or even higher temperatures, may be made available in the near future. Such materials could be used quite as well on steam turbines as on gas turbines. Hence, one may expect further increases in steam temperatures before long.

Superheater tubes present a difficult problem. The metals of these tubes are subject to a considerably higher temperature than the steam inside, hence require more heat-resistant alloys than the turbine or piping. Such high steam temperatures may necessitate gas temperatures over convection superheaters that exceed the softening point of the ash. Consequently, difficulties may arise in keeping such surfaces free of slag. This may lead to a more extended use of radiant superheater surface as part of the furnace walls, at least for the high-temperature portion of the superheater.

Higher Pressures

With an assumed limiting moisture content in the turbine exhaust of 10 to 12 per cent, higher initial steam temperatures permit the use of higher steam pressures. Steam pressures up to 2000 lb per sq in. are in use and a 2400-lb plant is nearing completion. When temperatures of the order of those stated in the preceding paragraph are possible, namely, 1200 F, pressures up to 2500 lb may be employed without reheating. There does not seem to be much gain at still higher pressures and the employment of the reheat cycle for such higher pressures involves costly steam-generator design.

The combined higher-temperature, higher-pressure expansion results in a greater heat drop. Even after allowance for decreased efficiency of the higher pressure blading, there will be a decrease in heat consumption per kilowatt-hour output over present types. With a given leaving loss from the limiting length of blades in the last row of the turbine, there can be an increased capacity of the turbine frame at the same time as increased economy.

Some may question the ability of the first row of turbine blades to stand higher pressures at light loads.

Much development work has been done on these blades. The action of such blading is now better understood and designers can meet this problem with more assurance of its successful solution than was the case a few years ago.

Larger Turbines at 3600 Rpm

One of the first Westinghouse turbines, a 400-kw unit built for Yale & Towne in 1901 operated at 3600 rpm. The first Allis-Chalmers unit in 1905, of 5500-kw capacity and one of the largest then built, operated at 750 rpm. Since these early days there has been a steady trend in design to higher revolutions per minute for large turbines.

At the present time, turbine designers limit the length of the last row of blades to about 20 in. on 3600-rpm units, partly due to wide spacing at the blade tips. This blade length with a 29-in. vacuum and normal leaving losses suffices for a turbine of about 25,000-kw maximum capacity in a single exhaust and about 50,000 kw in a double-flow exhaust on 3600-rpm machines. At lower vacuum or with somewhat higher leaving losses, larger capacity units can be furnished. The largest condensing turbine-generator under construction at 3600 rpm is the 65,000-kw tandem-compound unit for the new Harbor Station of the City of Los Angeles.

Some of the first large turbine-generators at 3600 rpm developed objectionable double-frequency vibration in the generator frame due to the effect of the two-pole revolving field. This vibration frequently was transmitted to other structures and led to noise having a disagreeably high pitch. The difficulty has been met by suspending the stationary winding and core on spring supports from the frame. The first General Electric unit of this type, of 25,000-kw capacity, is operating satisfactorily at the Westport Station, Baltimore. The first Westinghouse unit, of 65,000 kw employing a different type of support, operated smoothly on test. The transmission of this vibration to the outer frame of large units thus appears to have been reduced to acceptable limits.

Hydrogen cooling is becoming standard for units above 25,000 kw and results in improved generator efficiency. Successful means to seal glands, and to admit purging of generators have been developed. Hydrogen pressures up to 15 lb per sq in. may permit an increase of about 15 per cent in generator capacity over that with hydrogen at about atmospheric pressure.

The limiting size of a single-shaft turbine-generator set at 3600 rpm is now fixed by the maximum capacity of the generator, which, at the moment, is 65,000 kw. The development of steels permitting larger rotor diameters and improved means for securing rotor coils will permit increasing the generator size. Larger units than 65,000 kw are cross-compound.

While turbines of 3600 rpm may have better efficiencies than those of 1800 rpm in sizes below 50,000 kw, there appears to be little difference in efficiency in larger units due to high leaving losses. However, units at 3600 rpm will be chosen when available in somewhat larger sizes due to their smaller physical dimensions and less liability to damage from temperature changes. At this time, there seems little justification for the purchase of 1800 rpm units in sizes below 75,000 kw.

Modern condensers are designed to secure such longitudinal distribution of the steam that all surfaces receive steam in proportion to their condensing capacities. At the same time low pressure drop across tube banks, maximum cooling of the uncondensable gases to the air pump and reheating to vacuum temperature in the hotwell are also desired objectives. Vertical types of circulating pumps either of axial flow or the adjustable-blade propeller class are being increasingly used due to space saving and other advantages, such, for instance, as placing the motor above flood stages. Further developments in condenser tubes are desired to increase their service life.

Steam-Generating Plant

The steam-generating plant has been under continuous development since John Anderson successfully used pulverized fuel in the old Oneida Station at Milwaukee in 1919. At no time during the intervening period has it approached stable standardization, nor does this objective appear probable in the near future.

Developments in oil and gas burners may permit satisfactory operation at lower percentage of capacity than at present.

Improvements in coal pulverizers have reduced the power required for grinding and have increased the fineness of the product. Reductions in pulverizing costs of cements and other materials have been accomplished by two-stage grinding. It is suggested that two-stage grinding may offer further gains in the preparation costs of pulverized fuel. Uniformly sized coal to the mill also tends to reduce power for grinding. Slagging of boiler and superheater tubes by pulverized coal ash is still a troublesome problem. The nature of the fuel and rate of firing affects slag deposits. The solution to this problem appears to lie in fine grinding of the pulverized coal, wider spacing of superheater elements and lower velocity of the gases over them, proper location of soot blowers and perhaps in larger furnaces with lower heat release or in some cases special furnace arrangements as for instance the two-stage.

Practice in furnace-wall construction appears to favor the use of a solid bank of bare tubes. However, certain fuels and furnace designs employ refractory materials on portions of the walls. Dry-bottom furnaces may be used where coals with high ash-fusing temperatures are burned or where loads are variable and the boiler may stand by for a portion of the day. Wet-bottom furnaces are suited to coals with low ash-fusing temperatures and high load factors.

Disposal of Fine Ash a Problem

The economic disposal of pulverized coal ash is still an unsolved problem. Dry ash is a nuisance and granulated slag has little or no commercial value. Some method of usefully disposing of these materials in bulk should be possible of development. Here is an open field for experiments.

Many different steam-generator designs are available. One definite trend in all designs is toward the greater utilization of steaming surfaces exposed to radiant heat. Another trend is to give more attention to ample downcomers and to positive circulation circuits for the boiler water. In general, the furnace walls form the main radiant heat absorbing surface, but consideration must

also be given to the radiant heat emitted from the hot gases as they pass through the so-called convection surfaces. Sufficient convection surface may be placed between furnace and superheater to control the gas temperature to the convection superheater. This gas temperature should be sufficiently below the slagging point of the ash to avoid slag deposits on the superheater tubes when coal is used. Other convection surfaces beyond the superheater, if used, may serve as downcomers for circulating water and as means to reduce gas temperatures to economizers. The majority of the new steam generators purchased in the last few years are of the bent-tube type.

Superheater headers have nipples welded in place in the shops, and are annealed before shipment. The tubes are welded to these nipples in the field. There are many who believe that a similar procedure should be adopted for drums, headers and tubes of the boiler proper, in order to do away with the difficult operation of rolling tubes in place on high-pressure boilers to avoid leaks which often develop at the joints. Despite certain apparently valid objections that have been advanced from the standpoint of handling and erecting very large drums having welded nipples without incurring damage to the nipples, it is possible that such practice may eventually prevail for high-pressure work. In fact it is already being applied in the case of one large very high-pressure boiler now under construction.

Many types of steam washers and purifiers are in use, such as cyclones, bubble washers, wetted wire mesh and eliminators. The fluctuation of water levels over a considerable range with sudden load changes may require modifications of certain of these designs.

Superheat Control

The importance of control to secure constant superheat increases with higher steam temperatures. Various arrangements effect this control, such as by-pass dampers, combinations of convection and radiant superheater surfaces, divided furnaces with radiant superheaters, and desuperheating by means of tubes submerged in boiler water or otherwise. Control may also be effected by providing adjustable burners that may be deflected downward at heavy loads and upward at light loads. In some cases, control is secured with horizontal turbulent burners placed at different levels with the upper burners only used on light loads. An objective in many plants is to secure constant steam temperature over a wide range of load by means of such devices, for instance, from 40 per cent to full capacity.

With steam temperatures of 1000 F or above, the alloy tubes of superheaters will be glowing at their outlet ends. This raises the question of dissociation of the steam at high temperatures, which phenomenon may eventually prove to be the limiting factor in the use of high superheat. While research studies are being made, little data are at present available upon dissociation.

Power relief valves have been introduced to lessen the use and erosion of safety valves with high-pressure high-temperature steam.

Economizer designs appear to approach standardization with continuous pipe loops throughout. Present practice seems to favor a maximum water temperature leaving the economizer 50 F or more below boiler temperature rather than the earlier use of steaming economizers.

Boiler feedwater conditioning must be given much thought to insure proper operation of high-pressure boilers. It is generally believed that deaeration in addition to that which may occur in a surface condenser is necessary for the optimum removal of dissolved oxygen. Control of pH, of soluble solids, of sulphate-alkalinity ratios, of any residual oxygen, and of boiler water concentration are factors in satisfactory operation concerning which much can still be learned. Silica in feedwater still presents difficulties, although much progress has been made in the development of means for removing a portion of the silica. Deposits by the steam of solids on turbine blades have been lessened by careful water conditioning and concentration control but still require further study, particularly with regard to deposits of silica.

Piping needed with increased pressures and temperatures must be of alloy steel and quite thick. The design of this piping to prevent undue thrusts from expansion offers many difficulties. These pipe lines are now welded throughout.

The regenerative type of air preheater seems to be gaining preference over plate-type preheaters due to greater ease of maintenance and repairs.

Forced-Circulation Boilers

Water circulation in boilers continues to receive much study. The difficulty of maintaining natural circulation with very high boiler pressures naturally suggests forced circulation, which is widely used in Europe and one large high-pressure unit is under construction here. Among the advantages claimed are: lighter weight through the use of tubes of smaller diameter; any desired tube arrangement may be used, as the water is pumped through all tubes; and the tubes are comparatively free from scale troubles. The gland difficulties of the circulating pump for this service appear to have been overcome. An increased use of such boilers may be expected.

Station Economy

Obviously, increased pressures and temperatures with constant vacuum increases the heat drop and thus decreases the station steam rate. Extraction heating with three to five bleed points, further improves station economy. A decrease in Btu per kilowatt-hour should occur in these new high-pressure high-temperature stations.

A power station over its useful life will not operate continuously at either the most economical or the maximum load. Light loads must prevail during many hours of operation. Overall station performance at various capacity factors may be approximated by a form of Willans line. The slope of this line depends on the fuel requirements of the plant at no load with the main units spinning and at full voltage. The lower this no-load fuel consumption, the better will be the station economy at all loads, but particularly at light loads. A search for higher economy warrants a careful study of all auxiliary power requirements under such conditions in order to better the station performance as a whole.

Station Size

The superpower plant may have some disadvantages in case of war. While this country is not likely to be subject to aerial bombardment, the merits of a number of smaller plants scattered over the area of distribution deserves careful study. The unit installation of one boiler, one turbine in sizes up to 80,000 kw, together with the small labor force required, diminishes the advantages of the large plant. Outages on the whole system may be lessened by having several sources of supply available. Distribution losses may also be decreased.

A further factor to be considered in station size is chimney gases. Great volumes of rising hot gases are objectionable to airplanes. Since these heavy gases settle on cooling at varying distances from the chimney the concentration in surrounding neighborhoods must increase with increasing plant size. These factors favor a number of smaller stations.

Another consideration in chimney design is the objection from an aeronautical standpoint to tall chimneys. From a military point of view these offer excellent landmarks and range finders. Some German plants and several American stations have chimneys that do not project above the roof parapet. Gases from such chimneys tend to be carried down by eddies over the immediate plant surroundings. Hence a compromise on a medium chimney height appears desirable. Higher gas velocities may be needed at the chimney top to project the gas stream to a sufficient height to get the desired dispersion over adjacent regions.

This brief review does not permit as comprehensive a treatment of power costs as its importance deserves. However, the following comments are pertinent.

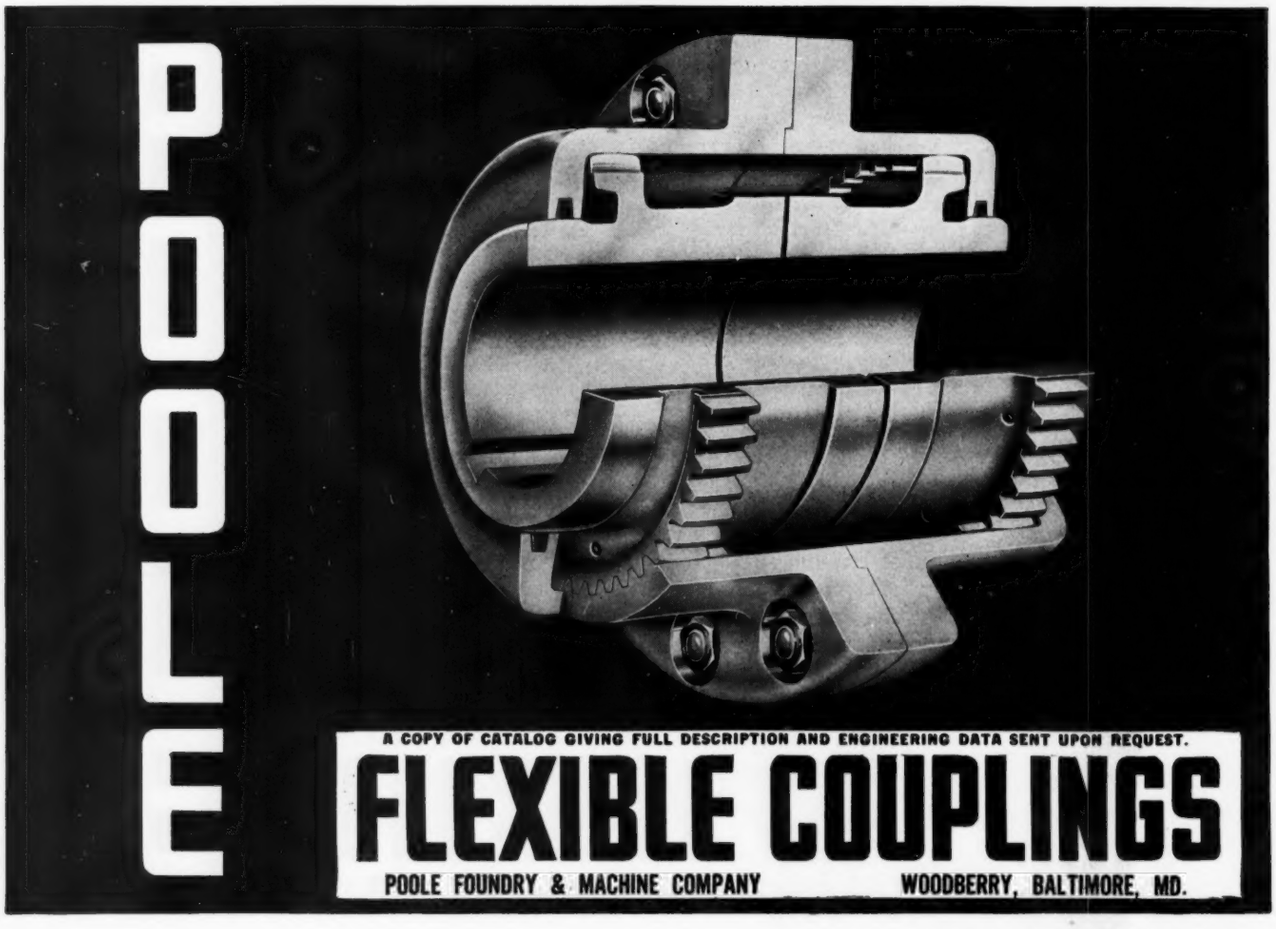
Larger units, lower fuel consumption and less labor per unit of output should tend to lower the cost of generating power. To offset this, the Government has raised coal prices and labor rates. These increases will ultimately be reflected in greater first costs of equipment and in increased operating fuel costs.

The net result will probably be little change or a slight decrease in the total unit cost of generating power. This will have little effect on the consumer's rates. The way to reduce rates to consumers is to have the customers increase the load factors on their installed capacity.

Conclusion

A full discussion of the trends in development of all equipment in the steam plant is impossible in so short a space. The preceding paragraphs direct attention to some of the more important factors and considerations.

This country is experiencing an increasing demand for power and many new steam-driven plants are being planned or are under construction. Due to the Emergency Defense demands on our manufacturers and the resultant congestion in production industries, it appears probable that some of the developments contemplated in the preceding paragraphs may have to be delayed for a more opportune time. However, the trends are plainly evident and these will assert themselves as soon as the present emergency conditions have passed.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Lampblack Fired Under Boiler at Honolulu Gas Co., Ltd.

Lampblack from a fuel-oil gas generator, containing up to 50 per cent moisture is hand-fired on the grates of a 20,000-lb per hr boiler which generates steam to run engine-driven gas compressors. A hollow refractory air-cooled wall and arches preheat the combustion air and the relatively high setting has resulted in the absence of smoke at rated output. The calculated overall efficiency is 73.8 per cent.

By T. C. BEATTY

Combustion Engineering Company, Inc.

THE Honolulu Gas Company, Ltd., supplies fuel gas to the "Pearl of the Pacific," made from ordinary fuel oil, commonly known as Bunker "C." Fig. 1 is an extended elevation of the double gas generator installed in 1930 which has a 4,000,000 cu ft daily capacity. Manufacturers of fuel gas will be interested to learn that this was the first commercial unit of its kind to be installed, and it grew out of a small pilot plant

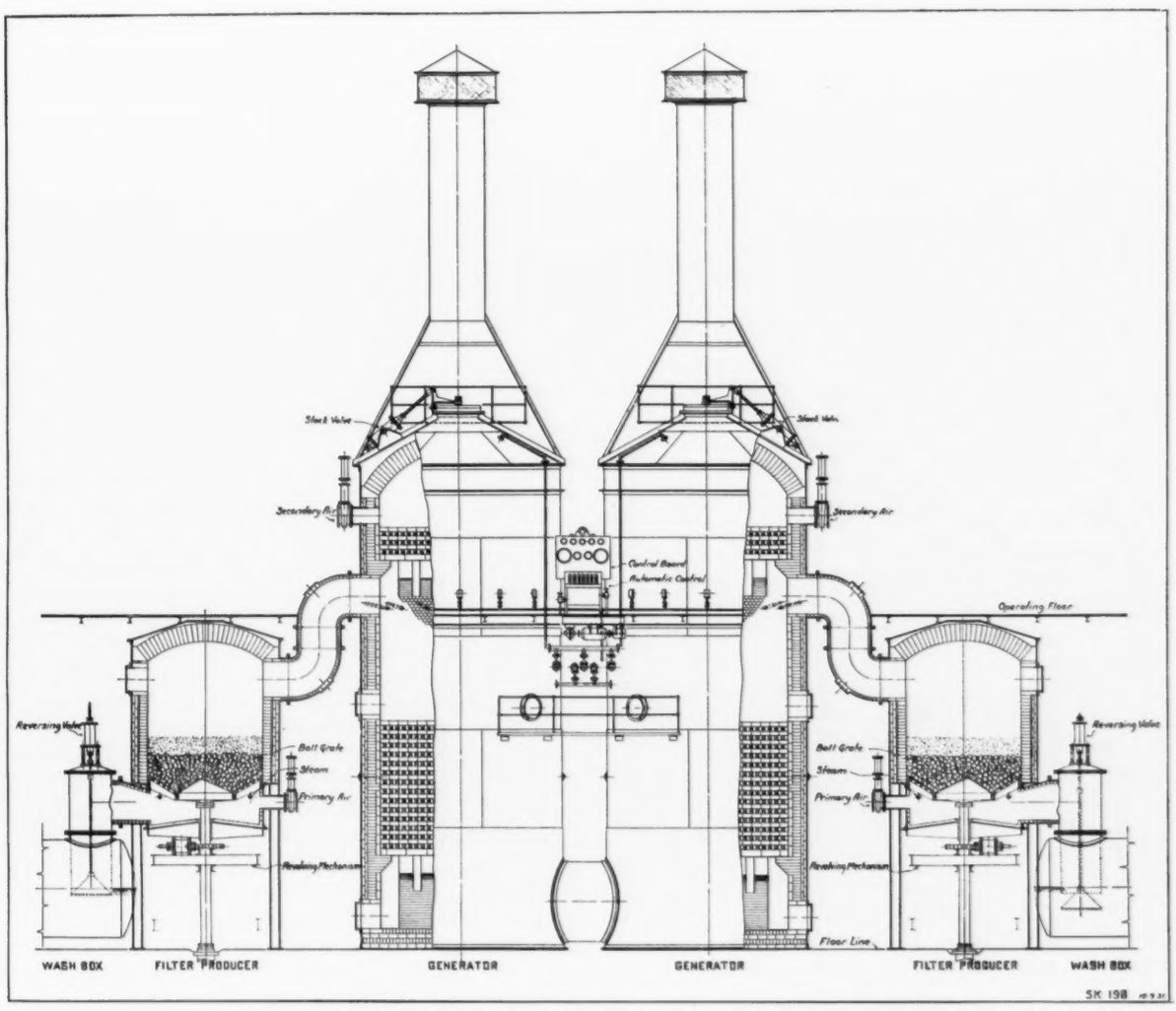


Fig. 1—Sketch of Jones gas process from which lampblack is available

designed and built in collaboration with one of the major utilities on the West Coast. Filter-producers in which lampblack is retained in the apparatus and subsequently used for producer gas and water gas were not included in the initial installation. They were added in November 1934, and for thirty months the gas generator unit was in continuous operation and established a record of consistent and efficient performance far in excess of the expectations of the designers.

As can be seen there are four shells comprising two generators and two filter-producers with a wash box after each reversing valve. Alternate runs are in

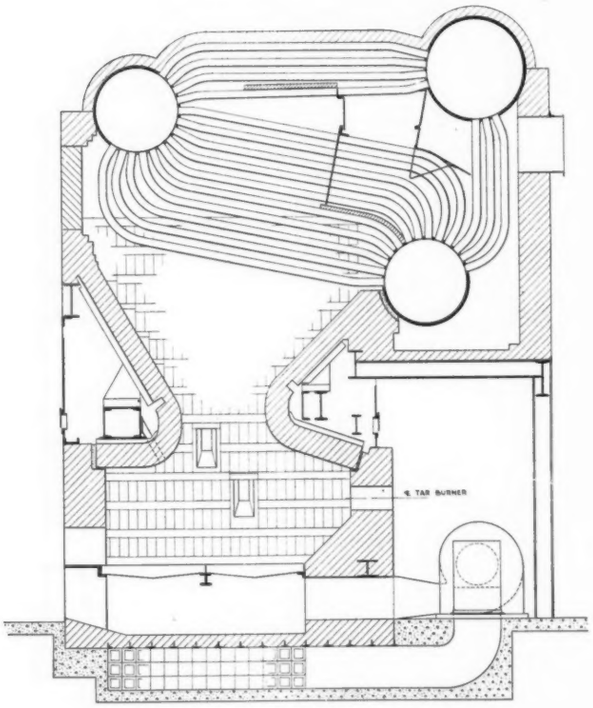


Fig. 2—Cross-section of boiler and setting

opposite directions through the set and the filter-producer alternately filters lampblack from the oil gas which, on subsequent runs, is used first for producer gas to reheat the oil gas checkers and then to make blue gas. The remainder of the lampblack is used as boiler fuel.

A typical oil analysis would run carbon 84.9, hydrogen 12.6, nitrogen 0.5, oxygen 1.0, sulphur 1.0 per cent and a heating value of approximately 18,500 Btu per lb. From this oil the patented oil gas apparatus generates fuel gas, having a heating value of approximately 519 Btu per cu ft, for use in the city.

Table 1 covering operating results will be of interest, keeping in mind that the data covers a run of twelve months, sometime after the gas generating unit was completed.

TABLE 1

(*a*)	Gas production, cu ft	586,932,000
(*b*)	Oil used, bbl	75,497
(*c*)	Lampblack produced, tons	3,072
(*d*)	Avg. daily gas production, cu ft	1,603,000
(*f*)	Operating load factor, per cent	40
(*g*)	Gas production per bbl of oil, cu ft	7,774
(*h*)	Oil use per 1000 cu ft of gas production, gal	5.4
(*i*)	Avg. calorific value of gas, Btu per cu ft	519
(*j*)	Btu in gas per gallon of oil used	96,000
(*k*)	Lampblack produced per 1000 cu ft of gas, lb	10.47
(*l*)	Steam produced from lampblack per 1000 cu ft gas, lb	110
(*m*)	Cost of oil per bbl.	$1.048
(*n*)	Cost of oil per 1000 cu ft gas	$0.135

Under these operating conditions the filtering was, at that time, imperfect and 10.47 lb of lampblack per 1000 cu ft of gas or 28.5 per cent of the carbon input passed the filter producers and was recovered from the wash boxes and used as boiler fuel. However, this is almost sufficient lampblack to generate all process steam and normal auxiliary requirements.

Lampblack, containing a large percentage of water, is recovered from the wash boxes and allowed to drain in two large open-top filters. One filter is continuously receiving the mixture while water drains from the other. From these filters lampblack is loaded in cars and rolled to the boiler house still containing some 50 per cent moisture where it is manually fired on horizontal grates. Dry lampblack is almost pure carbon and is an exceedingly fine powder. The approximate heating value is 14,540 Btu per lb, dry.

In the early days of this new gas-generator process on the Pacific coast, lampblack was hauled away to dump yards because it was considered too wet to burn under boilers. Later it was found that lampblack could be burned under boilers "if the boiler was set near the fire so as to absorb what little heat that was available." Consequently, all such boilers were set low, barely leaving space for a short front ignition arch. With this arrangement flame impingement on the first few rows of boiler tubes was the cause of considerable concern to plant operators, to say nothing of objectionable smoke.

Late in 1939 the Honolulu Gas Co., Ltd., decided to expand plant facilities which included installing a new boiler. After giving full consideration to all designs submitted it was decided that the unit and setting shown in Fig. 2, would best eliminate smoke while burning

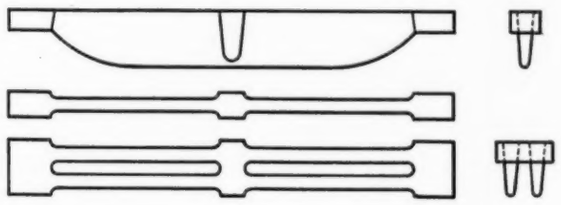


Fig. 3—Type of grates upon which lampblack is burned

lampblack and/or tar, another by-product. This unit is designed for 20,000 lb of steam per hour at 150 lb pressure, saturated, with 210 F feed. This pressure is dictated by reciprocating engines employed for driving gas compressors. Exhaust from the engines is used in the process. Up to this time smoke and fly ash were the source of considerable nuisance to adjacent property owners and the Gas Company was perfectly willing to increase its initial investment because of improved furnace design to eliminate all complaints.

A study of Fig. 2 shows ample furnace height has been provided to give the fuel time to burn completely before the products of combustion enter the tube bank. To improve combustion a double arch was provided to mix the rich and lean gases.

Furnace depth is limited to the distance a fireman can comfortably shovel lampblack for eight hours. This space is rather cramped for firing tar but because of the high efficiency of the new gas generators only a very small quantity is thrown off, consequently the rate at which tar is burned under the boiler is very low. Never-

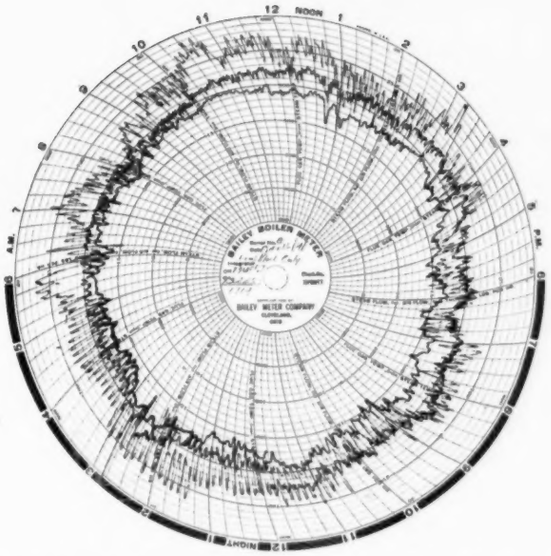


Fig. 4—Chart of operation when burning lampblack only

theless, it was decided to install overfire air nozzles in the front arch to eliminate smoke. The overfire-air fan motor is tied in electrically with a smoke indicator, or electric eye, located between the boiler outlet and stack and when smoke exceeds a predetermined value the fan starts automatically.

Sectionally supported air-cooled walls and arches were installed to reduce refractory maintenance. All air for combustion, when operating forced draft, enters the side walls and arches at the top and travels downward to a duct beneath the ashpit floor where it is led to the forced-draft fan located at the rear of the boiler. A short steel duct connects the forced-draft fan to the underside of the grates.

The grate bars are subjected to intense temperatures and it is agreed that the service is punishing due largely to the almost complete absence of ash in the fuel. The special castings used, Fig. 3, are the result of years of experimentation by the manufacturer.

The boiler has now been in continuous service for six months and the Chief Engineer reports a complete absence of smoke up to the capacity for which the unit was designed. Although designed for an output of 20,000 lb of steam per hour, it has carried peaks of 30,000 lb per hr with ease.

Fig. 4 is a chart taken January 16, 1941, while burning lampblack only and, with the aid of Fig. 5 and knowing the CO_2, a fair idea of performance can be had.

TABLE 2—PERFORMANCE

Evaporation, lb per hr	20,000
Exit gas temperature, F	540
CO_2, per cent	13
Weight of wet products, lb per lb of fuel	10.4
Excess air, per cent	62
Basic efficiency at 500 F exit gas temperature, per cent	75.25
Correction for 40 deg over base, per cent	1.45
Corrected efficiency, per cent	73.80

With this information it is fairly simple to calculate the weight of fuel, as fired, from:

$$\frac{\text{Evaporation} \times \text{heat in steam}}{\text{Heating value of fuel} \times \text{efficiency}} = \frac{20{,}000 \times 1018}{7270 \times 0.738} = 3800 \text{ lb per hr}$$

Steam per pound of fuel = 20,000 ÷ 3800 = 5.26 lbs.

With a grate area of 16 × 7 = 112 sq ft, the combustion rate becomes 3800 ÷ 112 = 33.9 lb per sq ft for the evaporation point under discussion.

The contractor was W. A. Ramsay, Ltd., local mechanical and electrical engineers and sugar mill machinery suppliers. A partial list of the equipment is as follows:

Boiler	Combustion Engineering Company
Valves	Walworth Company
Grate bars*	Paul David Engineers & Founders
Soot blowers*	Diamond Power Specialty Corp.
Feedwater regulator*	Northern Equipment Company
Air-cooled walls	Bigelow-Liptak Corp.
Refractories	A. P. Green Fire Brick Company
Fans	Buffalo Forge Company
F. D. fan drive (mechanical turbine)	General Electric Company
Boiler meter	Bailey Meter Company
Smoke indicator	T. W. McNeill Eng. Equip. Company

* Furnished by purchaser.

The author wishes to express his genuine appreciation to E. S. Jones, Chief Engineer of Honolulu Gas Co., Ltd., for his splendid cooperation and timely advice during the design of the new boiler and furnace, and also for descriptive material and operating data on his gas generator. It should also be mentioned that W. L. McKaig, Assistant Chief Engineer, designed the boiler house structural steel, the steel stack and foundations.

The Honolulu Gas Company has decided to add another double gas generator due to increased gas send-out, and because of the successful operation of this boiler and furnace a second practically duplicate boiler with sectionally supported air-cooled walls has just been ordered. The furnace of this unit will be designed for full-load operation when fired with lampblack or Bunker "C" oil. It was considered advisable to provide for oil firing in the event of insufficient, or no lampblack to maintain steam pressure at the engines.

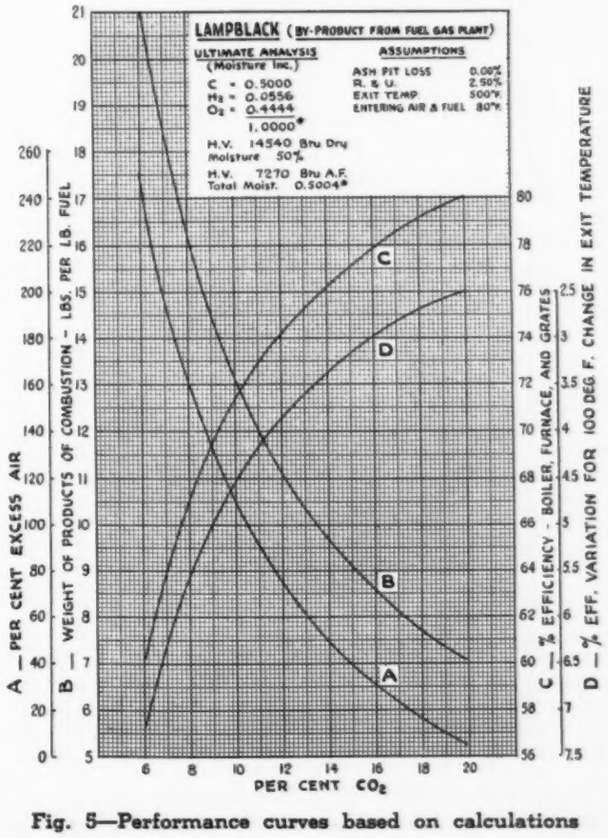
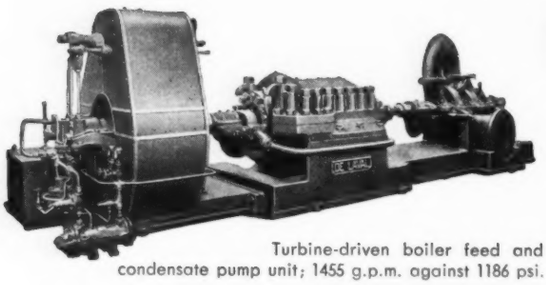

LAMPBLACK (BY-PRODUCT FROM FUEL GAS PLANT)
ULTIMATE ANALYSIS (Moisture Inc.)
C = 0.5000
H2 = 0.0556
O2 = 0.4444
1.0000*
H.V. 14540 Btu Dry
Moisture 50%
H.V. 7270 Btu A.F.
Total Moist. 0.5004*
ASSUMPTIONS
ASH PIT LOSS 0.00%
R. & U. 2.50%
EXIT TEMP 500°F.
ENTERING AIR & FUEL 80°F.
A — PER CENT EXCESS AIR
B — WEIGHT OF PRODUCTS OF COMBUSTION - LBS. PER LB. FUEL
C — % EFFICIENCY - BOILER, FURNACE, AND GRATES
D — % EFF. VARIATION FOR 100 DEG F. CHANGE IN EXIT TEMPERATURE
PER CENT CO2
A
B
C
D

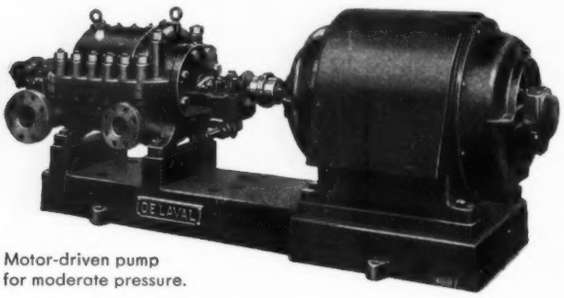
Fig. 5—Performance curves based on calculations

Whatever the capacity or pressure of your boilers or the temperature of the water

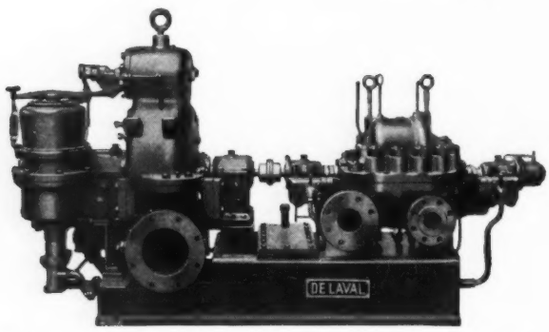


Turbine-driven boiler feed and condensate pump unit; 1455 g.p.m. against 1186 psi.

a DE LAVAL boiler feed pump is available



Motor-driven pump for moderate pressure.



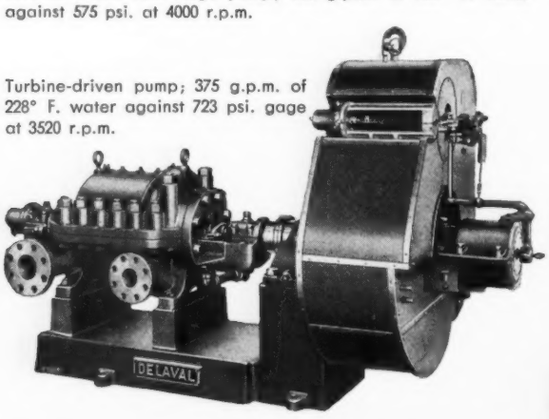
Turbine-driven four-stage pump; 300 g.p.m. of 235° F. water against 575 psi. at 4000 r.p.m.

Distinguishing features which enable De Laval pumps to meet successfully the most severe conditions of present day boiler plants are:

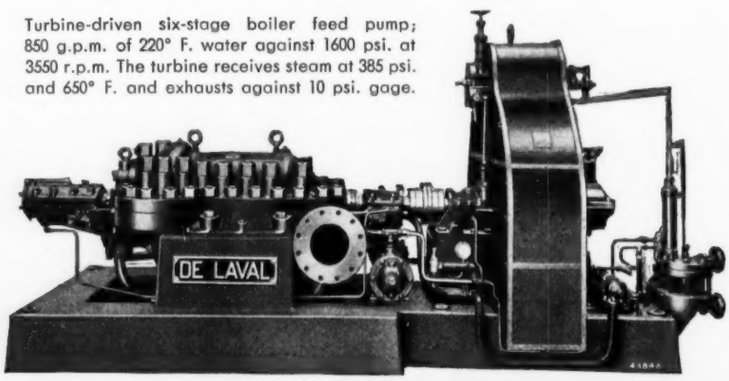
1. **Labyrinth wearing rings,** which permit greatly increased clearances for a given amount of leakage,
2. **Hydraulic axial balancing system,** which maintains rotor accurately in position without dependence upon a thrust bearing,
3. **Improved high quality alloys,** which meet the special requirements of the several parts, and
4. **Limit gage manufacture** upon an interchangeable basis, supplemented by
5. **Complete test** at the designed capacity, pressure and temperature before the pump leaves our shops.

Ask for Catalog P-3623.

Turbine-driven pump; 375 g.p.m. of 228° F. water against 723 psi. gage at 3520 r.p.m.



Turbine-driven six-stage boiler feed pump; 850 g.p.m. of 220° F. water against 1600 psi. at 3550 r.p.m. The turbine receives steam at 385 psi. and 650° F. and exhausts against 10 psi. gage.



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UTILIZING REFUSE COALS at 12th St. Station, Richmond, Va.

Excerpts from a paper presented at the Spring Meeting of the A.S.M.E. in Atlanta, Ga., relating experience in burning on a commercial scale various refuse coals as a blend or as an admixture with the better grades of coal from the Virginia and West Virginia Coal fields in the slagging-bottom furnaces of two large tangentially-fired high-pressure boilers.

By J. A. REICH
Supt. of Power Plants,
Virginia Electric & Power Co.

THE ability of a plant to burn successfully any given fuel is determined first by the type of equipment available and, second, by the service and load requirements demanded of the equipment. Normally, the object of burning any specified fuel is to obtain an economic advantage by securing the cheapest unit cost of steam generation. Since the advent of the national defense program we are confronted with another consideration. This is the possibility that the better grades of coal may become premium coals both in cost and in necessary governmental allocation to specified heavy industries. It is, therefore, becoming increasingly important from an economic and a civic viewpoint that the coal-burning potentialities of steam-generating equipment be also evaluated on the basis of its ability to burn one or more types of coal or "refuse." These thoughts gave especial value to recent experimentation on the burning of refuse coals in the high-pressure pulverized-coal-fired boilers at the 12th Street Station of the Virginia Electric and Power Company, Richmond, Va.

The boiler room of this plant contains two essentially duplicate 450,000-lb per hr pulverized-coal-fired steam-generating units operating at 900 lb 835 F. The furnaces are of the intermittent slag-tap type and are tangentially fired. Two bowl-type mills, each of 13 tons per hour capacity, with integral exhausters serve each unit.

In 1936 at the time of the first major step in the modernization and expansion of the 12th Street Station facilities the burning of a wide range of fuel was not seriously considered by the operating company or by the designing engineers. This point is of interest in that the subsequent use of sub-base and refuse coals was tried out on equipment not originally installed for the purpose and which therefore lacked the advantages of such design. As the steam-generating equipment was purchased on a guarantee based on the use of a specified quality of coal, it was the policy of the operating company first to establish efficient and stable operation within the fuel limits of the guarantee. After the elimination of preliminary operating problems and difficulties, attention was diverted to the use of small quantities of various grades of coal and to the consideration of the economics involved.

In 1937 this practice on a small scale was found to be economically feasible and worthy of a trial on a commercial basis. Approximately 20 per cent of the fuel burned in 1938 was outside of the range recommended by the equipment manufacturer. In the operating company's opinion this demonstration provided sufficient evidence to indicate that restricted narrow range fuel use was not necessary with the type of turbulent wet-bottom furnace installed. A second steam generating unit, a duplicate of the 1936 unit, was purchased and placed in service in 1939. The use of refuse coal was considered after the installation of the second unit.

The term "refuse coal" is here employed to mean coal of such low quality that from a disposal and usability standpoint in a given market area the coal approaches a worthless state. Virginia is fortunately supplied with excellent quality coals from the mine operations of Virginia and West Virginia. The local application of the term "refuse" is therefore relative to a market area supplied with excellent grades of coal.

Wide Range of Inferior Coals Available

A study of the coal market revealed that a number of so-called inferior coals and refuse coals were available in many nearby localities at economical prices on a Btu delivered basis. The refuse coals were marketed as bone coal, anthracite culm, local outcrop strippings, machine cuttings, mine dust, etc. In addition to this investigation of the refuse coals a study of the sub-base or inferior grades of Virginia and West Virginia coals was made for the purpose of creating, if possible, a maximum number of tested sources of supply, thereby minimizing procurement difficulties and insuring a continuity of fuel supply.

Preliminary studies and tests indicated that, in general, we had three groups of coal from which to select. The first was the premium coals which could be secured on the basis of desirable proximate analysis, grindability and ash fluid characteristics. The second group was the so-called inferior, sub-base, or high-ash coals which could be secured, but not on the basis of all desirable characteristics. The third group comprised refuse coals which only occasionally had any desirable feature other

than attractive thermal costs. The value of the second group lies primarily in the establishment of an increased number of fuel sources and not so much in a monetary saving.

Table 1 gives the average analysis of twelve representative fuels which were used at the 12th Street Station during the years 1939 and 1940.

Before using the Group 3 fuels on a commercial basis it was considered advisable from a public utility service standpoint first to consider the reduction in the maximum steam output due to the use of such fuels and to make the necessary provisions to protect against this loss in capacity. The logical solution to the problem was to provide an equipment arrangement whereby the refuse coal could be eliminated on short notice and a base coal substituted in its place.

The first step was to sectionalize the overhead coal-storage bunker with partitions in order to segregate the various grades of coal. In effect this produced a twin-

TABLE 1—AVERAGE ANALYSES OF REPRESENTATIVE FUELS USED IN PERIOD 1939–1940

	Proximate Analysis					Ash Temperature		
	Moisture, %	Volatile Matter, %	Fixed Carbon, %	Ash, %	As Recd., Btu/lb	Fusion, °F	Fluid, °F	Grindability
Group I								
Example (*a*)	2.11	23.12	71.22	3.55	14,875	2325	2450	91
Example (*b*)	1.88	16.15	76.64	5.33	14,720	2300	2400	103
Example (*c*)	2.62	22.99	68.23	6.16	14,365	2185	2290	102
Group 2								
Example (*a*)	3.91	31.60	56.72	7.77	13,864	2400	2550	65
Example (*b*)	3.55	21.68	65.68	9.09	13,720	2550	2725	100
Example (*c*)	2.52	17.32	68.82	11.34	13,441	2600	2715	95
Group 3								
Example (*a*)	6.25	16.17	62.29	15.29	12,019	2200	2300	100
Example (*b*)	1.51	14.00	63.80	20.69	11,794	3000	3000	75
Example (*c*)	4.67	24.79	52.64	17.90	11,679	2795	2975	85
Example (*d*)	5.42	23.93	53.08	17.57	11,660	2600	2750	80
Example (*e*)	7.42	10.65	64.06	17.87	11,309	2650	2775	85
Example (*f*)	11.87	10.94	55.68	21.51	9,878	2625	2750	82

unit type system of pulverized-coal firing with each unit supplied from a separate 400-ton coal-bunker section.

The second step was to install a totally enclosed screw-type cross conveyor between the two pulverizer units at the automatic coal scales, and thus to provide a means of supplying both pulverizer units from a single bunker. The bunker which can through the use of the cross conveyor supply both pulverizer units is known as the base coal bunker and the alternate bunker is known as the refuse-coal bunker.

Under normal operation the base coal is supplied to one mill and the refuse coal to the second mill. If load conditions are such that it is advisable to eliminate the use of the refuse coal the outlet gate on that bunker is closed and the cross conveyor operated. The cross-conveyor motor drive and the coal-scale motor drive are electrically interlocked and synchronized in such a way that the entire operation of the cross conveyor is automatic.

In addition to affording capacity protection for the steam generator the cross conveyor provides an ideal means of mixing or blending the base coal and the refuse coal in any desired proportion at the scale. This is accomplished by manually adjusting the inlet gate of the cross conveyor to carry a fixed percentage of the fuel load of the mill being supplied with refuse coal. In using anthracite culms and other refuse coals which do not exceed 10 per cent volatile content it has been found desirable to make adjustments of the cross conveyor to produce a blend of the refuse and base coal which has a volatile content of about 14 to 15 per cent. In using a very wet refuse slack, the moisture content of which is 7 to 8 per cent, it has also been found advantageous to produce a blend to improve feeding characteristics and promote mill drying. In general, the cross-conveyor arrangement facilitates the use and consumption of larger quantities of refuse coal than would otherwise be practical.

It was found that some of the refuse coals available, particularly the anthracite culms, were very fine and dry and that during conveying they created excessive dust nuisance in and around the station. The monetary saving that was possible through their use did not justify the expenditure of a large sum of money for dust control. However, the dust nuisance that was being experienced with anthracite culms was also being experienced with some of the best grades of coal. This condition is due to the fact that with the increased sale of domestic stokers the trend of coal preparation has been to the smaller sizes with the result that the slack available for steam generation contains a larger percentage of fines. It is possible that for the next several years the inherently dry slacks will become increasingly dusty and that conveying and handling difficulties will increase proportionately.

In order to obtain as many heat units per dollar as possible, dry shipment of coal and refuse have been advocated and treatment at the mines with water or with other material of little or no heat value has been discouraged. In general, the elimination of dust by surface treatments, whether at the mine or at the station, have proved to be ineffective or mechanically undesirable.

Equipment Installed to Cope With Prevailing Dust Condition

The plant was therefore confronted with the problem as to whether it would be obliged to eliminate all dusty coals and refuse. This solution would have been contrary to one of the main objectives which was to make use of as many sources of coal supply as possible. It, therefore, became desirable and we believe profitable to provide the necessary equipment to minimize the dust nuisance at the station and thus provide adequate facilities for unloading dry coals and dry refuse. Consequently, a conventional dust-control system for the unloading pit, the conveyors and the overhead bunker storage house was installed.

During the study of the available coal sources a proposal was made by one coal company covering the utilization of mine dust that was being produced in the preparation of dedusted domestic-size coal and through the use of mine-dust control equipment. The dust was comparable in size to that being produced by the plant pulverizers, that is, 85 per cent through 200-mesh, 95 per cent through 100-mesh and a maximum of 1 per cent held by a 60-mesh screen. An investigation indicated that the supply of dust would be of such quantity and continuity that the purchase of experimental equipment to unload, convey and utilize the dust was justified. The necessary equipment consisted of a track unloading pit, a pneumatic dust pump, a 40-ton storage silo located in one corner of the station slack coal bunker and a table-type feeder.

The dust is delivered to the plant in covered railroad cars, the hopper bottoms of which are equipped with sliding-type gates, and the gate outlets are arranged so that a canvas duct can be connected between the gates and the dust pump. The contents are conveyed by way of the pump to the overhead silo. From the silo the dust is used to operate the pulverized fuel fired boilers or to supplement a pulverizer in operation. This dust coal is of excellent quality and no operating difficulty is experienced in its use.

It is of interest to note that the Bituminous Coal Commission in establishing the recent minimum coal prices stated that due to the experimental work conducted at the 12th Street Station of the Virginia Electric and Power Company on the utilization of mine dust, the said company would be allowed to purchase from the coal company 110 tons per day of the dust at a price of 40 cents per ton below the established Code price of the operator's $^3/_8 \times$ 0-in. slack size.

In order to utilize the various grades of coal and refuse coal offered by the coal market it was found desirable or necessary to provide at an approximate cost at $50,000 the following equipment or equipment arrangements:

1. Divided coal bunkers.
2. A cross conveyor to maintain high rating capacity and facilitate blending and mixing of refuse coals and base coals.
3. Dust-control equipment.
4. Dust-unloading, conveying and feed equipment.

The refuse coals used to date have had relatively high grindability indices of 75 Hardgrove, or higher. The grinding of these coals has afforded no great difficulties and in consideration of the cross-conveyor protection their use has not penalized the station through a reduction of steam-generating capacity.

High Versus Low-Volatile Coals

The higher volatile refuse coals have been found to have ignition and flame stability advantages over the lower volatile fuels. In using the refuse coals low in volatile content, 10 to 12 per cent, it has been found desirable to maintain a higher degree of pulverization (85 per cent through a 200-mesh screen) and secondary air adjustments such as to impinge the flame directly against the slag bed. A slag-bed temperature of 2300 F has been found highly desirable in using the low-volatile refuse coals. This provides a necessary concentration of heat near the burners in order to promote and facilitate ignition.

One of the most important considerations in the utilization of refuse coal is that of the ash characteristic in its relation to the operation of slag-tapping equipment and the formation of slag deposits on the heating surfaces of the furnace and boiler. This problem assumes large proportion because of the fact that refuse coals are usually high in ash and the ash is usually refractory in nature.

The furnace temperature and the slag-bed temperature are within limits determined by the quantity and temperature of the primary and secondary air supplied with the fuel and by the rate of heat liberation in the furnace. At the 12th Street Station it is desirable to maintain about 116 per cent total air (16.5 per cent CO_2) at the furnace outlet in order to obtain the desired steam superheat.

Through considerable experimentation and observation it has been found that most of the coals having an ash fluid temperature of 2500 F can be tapped with relative ease at a boiler rating of about 300,000 lb per hr. The coals having an ash-fluid temperature of 2650 F either require an increase in rating to about 400,000 lb per hr or a reduction in total air to 111 per cent (17.5 per cent CO_2) at the furnace outlet in order to obtain the same relative ease of slag tapping. In increasing the rating from 300,000 to 400,000 lb per hr the heat liberation is increased from 18,000 Btu per cu ft to 25,000 Btu and the slag bed temperature after equilibrium is established is increased about 200 deg F. The decrease of total air from 116 to 111 per cent (16.5 per cent CO_2 to 17.5 per cent CO_2) slightly lowers the gross heat liberation and increases the slag bed temperature about 100 deg F, or approximately one-half that of the rating increase. The effectiveness of the air adjustment after a lapse of several hours is probably due to a conversion of some of the complex ash constituents under the less oxidizing slag bed zone atmosphere as well as to the 100-deg increase in slag-bed temperature. Recent tests on samples from the slag bed after operating at 17.5 per cent CO_2 indicated that a large portion of the iron present was in the form of ferrous oxide. Samples of the fly ash taken at the same time however indicated that a large percentage of the iron present was as ferric oxide. The fluid temperature of the fly ash in both cases was approximately 100 deg higher than the slag samples taken at the same time.

TABLE 2—ANALYSES OF COAL FIRED, SLAG AND FLY ASH

	Fe_2O_3, %	FeO, %	Fusion Temp., °F	Fluid Temp., °F
Ash as fired	11.38	0	2350	2452
Slag sample S-17	2.14	11.18	2305	2386
Slag sample S-18	0.43	10.32	2345	2411
Slag sample S-19	1.90	8.51	2356	2421
Slag sample S-20	1.09	12.49	2320	2396
Fly ash sample FA-19	4.98	1.45	2391	2502
Fly ash sample FA-20	7.74	1.02	2487	2624

Employment of Fluxing Ash

In a preliminary review of the refuse coals available it was early recognized that their ash characteristics in general were such that tapping the ash of some of these fuels would be difficult except with the use of a flux, with the simultaneous use of a coal with an ash having fluxing characteristics, or with the intermittent use of a fluxing ash to purge the slag formation. The plant laboratory investigated a number of coals having low ash-fluid temperatures and evaluated them on the basis of their value as fluxing coals. The tests were conducted primarily to obtain the effect of mixing the coals on the ash-fusion and fluid temperatures of the mixtures of the high-fusion refuse coals and the low-fusion base coals.

The plant operating department was at first reluctant to accept the results of the tests on the mixtures as being indicative of the results which could be expected in actual operation. It was thought that the mechanics of mixing the ash in the laboratory and the results obtained from the gas-fired ash-fusion furnace were not comparable to actual firing conditions and that the results obtained would give erroneous indications. The absolute values of the laboratory furnace determinations were also

questioned because of difference in atmospheric firing condition in the laboratory furnace and in the steam-generator furnace. However, subsequent trial of the high-fusion refuse coals as mixtures with the low-fusion coals under boiler tests substantiated the value of the laboratory furnace as a worthy gage in predicting the characteristics of the ash in the slag bed of the pulverized-fuel-fired unit.

TABLE 3
PROXIMATE ANALYSIS OF COALS
(Moisture Free Basis)

Mine	Volatile Matter, %	Fixed Carbon, %	Ash, %	Heat Value Btu/Lb	Btu/Lb, Ash-Free	Sulphur, %	Grindability (*H*)
A	14.92	76.75	8.33	14,229	15,521	4.17	99
B	22.45	70.33	7.22	14,680	15,822	0.49	103
C	18.55	76.81	4.64	15,169	15,907	0.63	105
D	16.79	77.87	5.34	14,968	15,812	0.61	105
E	16.32	78.24	5.44	14,947	15,807	0.47	111
F	35.55	61.19	3.26	14,893	15,395	0.45	58
G	17.08	76.92	6.00	14,952	15,906	0.48	101
H	24.45	71.52	4.03	15,170	15,807	1.22	103
I	12.35	66.49	21.16	12,134	15,391	1.02	93
J	18.32	63.38	18.30	12,551	15,362	1.18	97
K	18.44	73.41	8.15	14,508	15,795	0.53	97
L	22.38	66.69	10.93	14,004	15,722	1.70	97
M	9.69	72.81	17.50	12,550	15,212	0.44	81
N	18.41	76.54	5.05	15,107	15,745	0.90	106
O	21.19	73.38	5.43	15,024	15,887	0.75	103
P	16.61	72.26	11.13	13,996	15,749	0.90	93
Q	11.59	69.65	18.76	12,390	15,258	0.51	84
R	23.40	67.38	9.22	14,370	15,829	0.77	100
S	13.49	64.04	22.47	11,975	15,446	0.52	74

COAL ASH ANALYSIS

Mine	SiO_2, %	Al_2O_3, %	Fe_2O_3, %	CaO, %	MgO, %	SiO_2, Al_2O_3	Fe_2O_3, CaO, MgO	Ratio Refrac. / Fluxing	Ash Fusion, °F	Ash Fluid, °F
A	39.82	19.52	40.30	0.26	0.10	59.34	40.66	1.46	2054	2183
B	37.76	26.23	12.11	21.03	2.87	63.99	36.01	1.78	2148	2346
C	40.65	28.61	18.17	10.62	1.95	69.26	30.74	2.25	2269	2406
D	38.95	26.82	15.03	17.10	2.10	65.77	34.23	1.92	2313	2422
E	44.15	29.75	9.63	13.79	2.68	73.90	26.10	2.83	2274	2429
F	44.73	29.89	16.94	6.42	2.02	74.62	25.38	2.94	2237	2450
G	45.37	30.61	12.87	10.06	1.09	75.98	24.02	3.16	2340	2452
H	38.08	28.42	32.24	0.62	0.64	66.50	33.50	1.99	2406	2520
I	56.02	32.15	4.95	5.67	1.21	88.17	11.83	7.45	2457	2599
J	61.84	27.26	9.27	0.88	0.75	89.10	10.90	8.17	2558	2680
K	57.26	29.17	9.84	3.00	0.73	86.43	13.57	6.37	2604	2695
L	47.91	34.56	15.60	1.66	0.27	82.47	17.53	4.70	2609	2708
M	57.25	32.25	4.16	4.94	1.40	89.50	10.50	8.52	2624	2746
N	47.32	36.35	14.79	0.72	0.82	83.67	16.33	5.12	2673	2781
O	53.98	33.55	10.73	0.77	0.97	87.53	12.47	7.02	2662	2786
P	52.07	30.65	10.75	6.03	0.50	82.72	17.28	4.79	2708	2809
Q	65.09	25.20	5.93	3.03	0.75	90.29	9.71	9.30	2746	2857
R	55.04	32.93	10.88	0.28	0.87	87.97	12.03	7.31	2805	2870
S	67.71	28.45	3.14	0.38	0.32	96.16	3.84	25.04	2900	2900

The components of the ash analyses were divided into two groups; the refractory group consisting of SiO_2 and Al_2O_3 and the fluxing group consisting of Fe_2O_3, CaO and MgO. The ratio of the refractory to the fluxing components of each ash was determined. It is of interest to note that the coals with fusion temperatures of 2400 F and less had ratios varying from 1.46 to 3.16, while those with fusion temperatures of 2400 F and higher had ratios of 4.7 to 25.04.

Under actual plant operation fuels *B* and *H* (Table 3) were found to be excellent fluxing fuels. Fuel *H* is very effective in purging the slag bed when the temperature of the slag is maintained at about 2500 F. Fuel *B* is an excellent purging fuel for the furnace side walls, but in combination with fuels *L* and Q it has been found to be conducive of an ash nesting in the superheater. Fuel *F* has not been used extensively, but operation notes indicate that it has a very effective slag bed fluxing action.

It is of particular interest to note that the fuel ash *H* containing a large percentage of Fe_2O_3 and a small quantity of CaO and MgO and the fuel ash *B* containing a relatively small quantity of Fe_2O_3 and a large quantity of CaO and MgO are rated the best fluxing fuels by the operating personnel.

About 10,000 tons of fuel *S* have been used and extensive observations made because of its extreme refractory nature. Some doubt exists as to the advisability of its use because of the difficulty experienced in getting its ash to dissolve in the slag bed. It is highly resistant to the fluxing action of any of the coals *A* through *H*. Laboratory tests indicated that a small quantity of calcium was effective in reducing the refractory nature of the ash, but this has not been tried in the boiler furnace at this writing.

In reviewing the 12th Street Station steam-generator operation over the past three years a steady progress toward the use of refuse coal on a commercial basis can be noted. The theory of narrow range fuel use to obtain the most satisfactory operation of the relatively low heat release wet-bottom furnaces was early regarded as an unnecessary restriction. It was admittedly the course of least resistance, but also a course which failed to capitalize on the capability of the equipment. Through the expenditure of a relatively small sum of money to provide a cross conveyor the steam-generating capacity of the unit was protected and the use of refuse coal made possible.

The establishment, as herein noted, of the ability to burn refuse coal has resulted in a decreased overall cost of steam generation, provided a wider field for coal procurement, and protected the station against a market condition in which the narrow range of fuel was not readily available.

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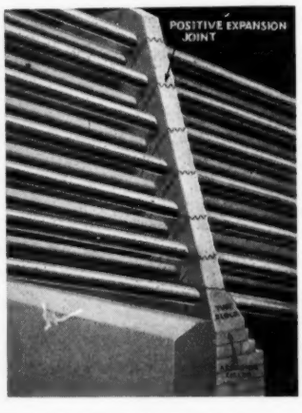

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By JOHN M. DRABELLE, Cons. Engr.
Iowa Electric Light & Power Co.

THE modern heat cycle in steam power plants has brought into the power plant numerous heat exchangers, usually involving exchange of heat from steam under various pressures and temperatures to water going to the boiler, and even in some cases water-to-water heat exchangers in addition to the conventional oil-to-water lubricating oil cooler and air-to-water generator air cooler. In addition the diesel engine station with the larger units involves water-to-water exchangers for the cooling of cylinders, and lubricating oil-to-water exchangers for cooling lubricating oil, both for bearing lubrication and internal cooling of pistons.

The high rates of heat transfer and low terminal differences of these various devices make it imperative that the surfaces be kept clean in order that the cycle efficiency may be maintained. Keeping these surfaces clean is easier said than done.

For several years past we have been experimenting with various cleaning agents and methods of cleaning for the removal of slimes on the oil side of lubricating-oil coolers, both for steam turbines and for diesel engines. The material called "Oakite" which can be purchased in any grocery store does a most excellent job. The success of its application, however, depends on keeping the solution in motion. This can be accomplished by either a steam or compressed-air jet and keeping the solution heated to not less than 160 F. A convenient method of doing this is to make a cylindrical tank out of two old oil barrels, cutting both heads out of one and then welding the two together. The solution is mixed in this tank; then the tube bundle lowered into the tank by means of the station crane or a chain block, and the air jet turned on. It is better to use two solutions of cleaner of moderate strength than to attempt to do all of the cleaning with one solution of high strength.

For cleaning water surfaces two methods are available; one is the use of an inhibited muriatic or hydrochloric acid, and the other lactic acid. Again the rule of solutions of moderate strength applies, with the solutions at temperatures of 160 to 180 F and positive circulation. After the cleaning is completed, the device cleaned should be thoroughly and carefully washed and flushed with clean water; then as a further precaution a weak solution of soda ash should be pumped through to neutralize any remaining acid, followed again by a clean water wash. Inhibited muriatic acid can be purchased from chemical houses already prepared for use, or one can make up his own acid solutions by purchasing these inhibitors from such chemical companies as the Monsanto Chemical Company or the Carbide and Carbon Chemicals Corporation. The former suggests the following procedure:

The application of inhibited muriatic acid to the cleaning of any equipment is something which should be handled carefully and in accordance with local conditions. In other words, care and caution should be the rule until sufficient experience has been obtained to work out

* Excerpts from a talk before the Missouri Valley Electric Association.

Non-Return Valves for TURBINE BLEEDER LINES

Balanced Action . . . Davis Non-Return Valves have finely balanced action through use of a counterweighted lever which balances disc assembly. Rugged construction insures smooth operation and long, trouble-free service. For extreme operating conditions, an outside oil dashpot is available. Balanced spring-loaded valves can also be furnished for non-return service.

Straight Flow . . . Disc swings up so that the direction of flow is in a straight line, without obstruction. Pressure drop across Davis Non-Return Valves is negligible.

Auxiliary Control . . . Either an auxiliary trip-lever or an oil cylinder can be furnished on Davis Non-Return Valves to provide emergency closing when the turbine oiling system fails. Reestablishing oil pressure releases auxiliary closing force and valve is free to operate as a balanced check valve.

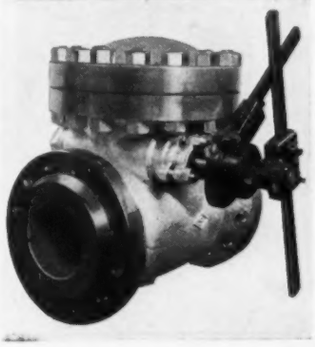
For Pressures up to 600 lbs. Sizes from 3″ to 24″. Steel or semi-steel bodies, with bronze, monel, or stainless steel trim.

Write for Complete Data. DAVIS REGULATOR CO., 2510 S. Washtenaw Ave., Chicago, Ill.

At Top—Davis No. 134 Balanced Check Valve. Simple in design, positive in action and dependable in service.

Right—Davis Non-Return Valve, equipped with auxiliary oil control cylinder for emergency closing.

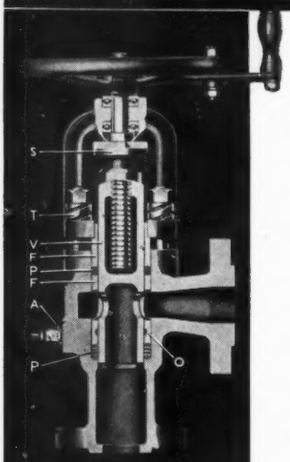
Below—Davis Balanced Check Valve, with trip lever for auxiliary operation.



DAVIS REGULATOR CO.

YARWAY EQUIPPED . .

A Mark of Good Engineering

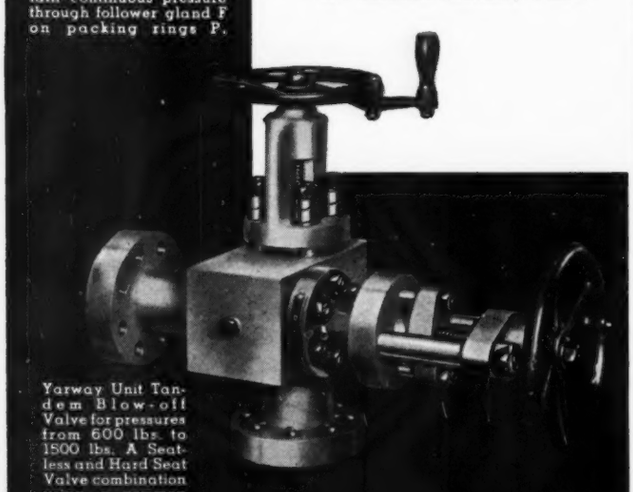


Yarway Seatless Blow-off Valve. Operation: After Valve is closed, shoulder S on plunger V contacts with upper follower gland F, forcing it down into body and compressing packing P above and below port. Annular groove O connects with Alemite fitting A for lubricating plunger and packing. Yoke springs T maintain continuous pressure through follower gland F on packing rings P.

Yarway Blow-off Valves are used singly or in tandem in more than 12,000 plants in 67 different industries . . . Regarded as a standard of quality by leading steam plant designers and builders of steam generating equipment...Selected for Federal, State and Municipal Institutions...Built for all pressures up to 2,500 lb. . . . Write for Catalog — Section B-420, up to 400 lb. pressure; Section B-430 for higher pressures.

YARNALL-WARING COMPANY

101 Mermaid Avenue, Phila.



Yarway Unit Tandem Blow-off Valve for pressures from 600 lbs. to 1500 lbs. A Seatless and Hard Seat Valve combination using a common forged steel body.

YARWAY

BLOW-OFF VALVES

methods of procedure, depending upon the type of equipment to be cleaned. There are three factors in cleaning: (*a*) the strength of the acid; (*b*) the length of time that the acid solution is allowed to stay in the equipment; (*c*) the thickness and kind of scale. The reason for this is that the amount of deposit varies materially, the substances which make up the deposits vary, and the quantity circulated per minute varies with various applications. The safest rule seems to be to proceed with a comparatively weak acid solution applied for a short length of time, say a 2-per cent solution of inhibited hydrochloric acid circulated for a period of fifteen minutes. Then observe the condition of the deposit in the equipment and determine whether it is advisable to increase the strength of the acid, the period of application or both.

Assuming that 18-deg muriatic acid is purchased, this has a strength of 27.92 per cent hydrochloric acid. To a carboy of acid (11 gal) is added one pound of "Hibitite," and then the acid is diluted to a strength of approximately 2-per cent hydrochloric acid. A 2-per cent solution consists of one gallon of 18-deg acid and fifteen gallons of water. A 4-per cent solution would be a gallon of acid and seven and one-half gallons of water. The usual care in handling acids should be observed, such as the use of rubber gloves, goggles, protective rubber apron and the acid poured slowly into the water; under no circumstances should water ever be poured into the acid.

The 2-per cent solution should then be circulated through the equipment to be cleaned for about twenty minutes. Then drain out the acid solution, wash the object to be cleaned with fresh water and observe the progress in scale removal. If scale is left, another application should be made until the equipment is cleaned. Experience definitely dictates the use of the weaker solutions for a longer time rather than the strong solutions for a shorter time. Pumped circulation of the acid solution should be used whenever it can possibly be applied as the scouring action of the flow of the fluid materially assists in the cleaning.

In reference to the use of organic acids, such as lactic acid, for several years we have experimented and have used solutions of lactic acid for the cleaning of heat exchangers and in some cases horizontal return-tubular boilers. For such work commercial grade 44-per cent lactic acid is purchased from the chemical or wholesale drug houses, and a solution made up of approximately one gallon of acid to twenty gallons of water. The application of heat considerably accelerates the action of this acid, and in the case of cleaning of an h.r.t. boiler, the manhole head is removed and the boiler filled with water to within eight inches of the lip. Acid is then poured into the water, and a very light fire built. This sets up the necessary circulation, and at the end of eight hours or when foaming ceases, the fire is killed, the boiler cooled and drained and flushed with water. An inspection is then made as to the amount of scale removed. If further cleaning is necessary the procedure is repeated. This method is particularly advantageous in removing scale from between tubes of small boilers that it is difficult and practically impossible to reach with mechanical cleaners. For killing the acid after final cleaning is completed, the boiler is filled with water, two bucketfuls of soda ash are added and the solution boiled for about two hours. This results in completely neutralizing any remaining acid present.

The same general procedure is followed in reference to heat exchangers and other devices.

Inhibitors are usually chemical compounds sold under trade names and their action is to cause the acid to attack scale in the form of calcium and magnesium and not to attack iron, steel, muntz or admiralty metals or other similar materials used in heat exchangers. Chemical cleaning offers numerous advantages, but like anything else it must be used with care, caution, good judgment and particularly several gallons of common sense.

A very complete discussion of scale formation and removal will be found in Research Series No. 74 of the Engineering Experiment Station of Purdue University.

M-D Turbine to Have Turning Gears

Motor-driven turning gears will be incorporated for the first time in mechanical-drive turbines when three special units now being built by the General Electric Company are completed for the Consolidated Edison Company's Sherman Creek station.

The turbines, rated 1685 hp at 4340 rpm, are to be of the condensing automatic-extraction type, and will be used for boiler-feed-pump drive. Two of the units will be in operation at all times, with the third standing by as a spare.

The turning device will keep the rotor of the spare moving at approximately 10 rpm, so that it can be put on the line immediately without requiring any preliminary warm-up. Uniform temperature distribution will be maintained in the slowly turning rotor while cooling, eliminating the possibility of distortion in the shaft.

FOR THE TOUGH JOBS

Carey MAGNESIA • ASBESTOS HEAT INSULATIONS

At the plant of the Otis Steel Company, Cleveland, steel sheets to be annealed are stacked on bases and covered with corrugated steel hoods. Gas furnaces are then swung over the hoods.

In these annealing operations, the bases are subjected to extreme heat and heavy loads. In previous experience, the bases broke down after 50 heats—had to be rebuilt. Since rebuilding with CAREY HI-TEMP and 85% MAGNESIA, the bases are as good as new after 50 heats.

The tougher the job, the more you need CAREY Insulations. Whatever your insulation problem, put it up to CAREY. Write for Insulation Catalog—address Dept. 69.

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Getting Slow Deliveries?

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No need to wait for delayed deliveries or build up large inventories of refractory tiles or special fire clay shapes.

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Simply mix Moldit with water and pour or cast like concrete into any size or shape, or make any monolithic lining.

Moldit air sets to preburned refractory hardness and requires no "baking out." It is heat resistant to 2600° F. and does not spall, puff, bloat, shrink or crack due to temperature fluctuations.

For real time and money savings—try Moldit. Write for Bulletin No. R-33.

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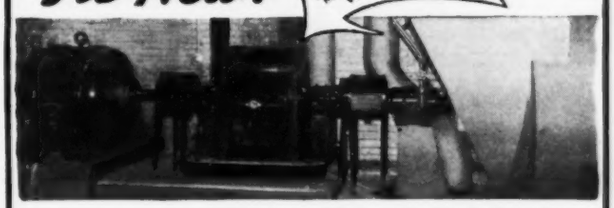

It's Accepted!

QUESTION: "How to get simple, easily controllable, effective, efficient, variable delivery from boiler draft fans?"

ANSWER: "Use *E-M Magnetic Variable-Speed Drive* units between motors and fans."

Fill out the coupon below, send it to Electric Machinery Mfg. Co. and we will send you our 12-page booklet, MD-3, presenting the principles, characteristics, advantages, and constructional forms of the Magnetic Drive.

ELECTRIC MACHINERY MFG. CO., MINNEAPOLIS, MINN.

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33

NEW CATALOGS AND BULLETINS

Any of these publications will be sent on request.

Direct-Fired Systems

A new catalog has just been issued by Combustion Engineering Company, Inc., New York, which incorporates the latest improvements in mills and burners as well as many of the latest installation drawings of steam-generating units covering a wide range of capacity and pressure.

The design improvements include changes in the bowl mill classifier arrangement and a new feeder drive; adjustable feature of the tangential burners and the elimination of all refractory around these corner burners; and changes in the horizontal turbulent burner, in which the distributing vanes for secondary air are now placed within the boiler front. Details of all essential parts are shown by cut-away wash drawings and photographs. There is also a section on impact mills and on pulverized coal furnaces.

The catalog covers 36 pages and contains 50 illustrations.

Condenser Repairs

Bulletin No. C-41 on the C & C Method of Condenser Renovation describes its method of removing defective tubes or reconditioning defective tube ends by pulling, cutting and re-rolling. It is claimed that 15 to 20 tubes per minute may be extracted or cut from the tube sheet by this method which is illustrated in both photographs and diagrams.

D-C Motors

A very informative 8-page booklet has just been issued by the General Electric Company, Schenectady, N. Y., entitled "How to Maintain D-C Motors" (GEA-3488). The object of the booklet is to provide the maintenance man with basic rules and facts, and a method of organizing his work that will insure full and reliable motor service. A symptom, cause and remedy chart is given, together with a concise inspection schedule.

Hot-Process Softeners

A new 48-page catalog on hot process water softeners for removal of hardness, silica and other scale-forming material from boiler feed and industrial process waters has been published by Cochrane Corporation. The book contains a nine-page appendix of feedwater chemistry, in addition to heat balances, flow diagrams, two-color construction drawings, and engineering tables and charts. Effective treatments for all water conditions are discussed. Various types of installations are diagrammed and considerable space is devoted to illustrations and descriptions of accessory equipments and their various functions.

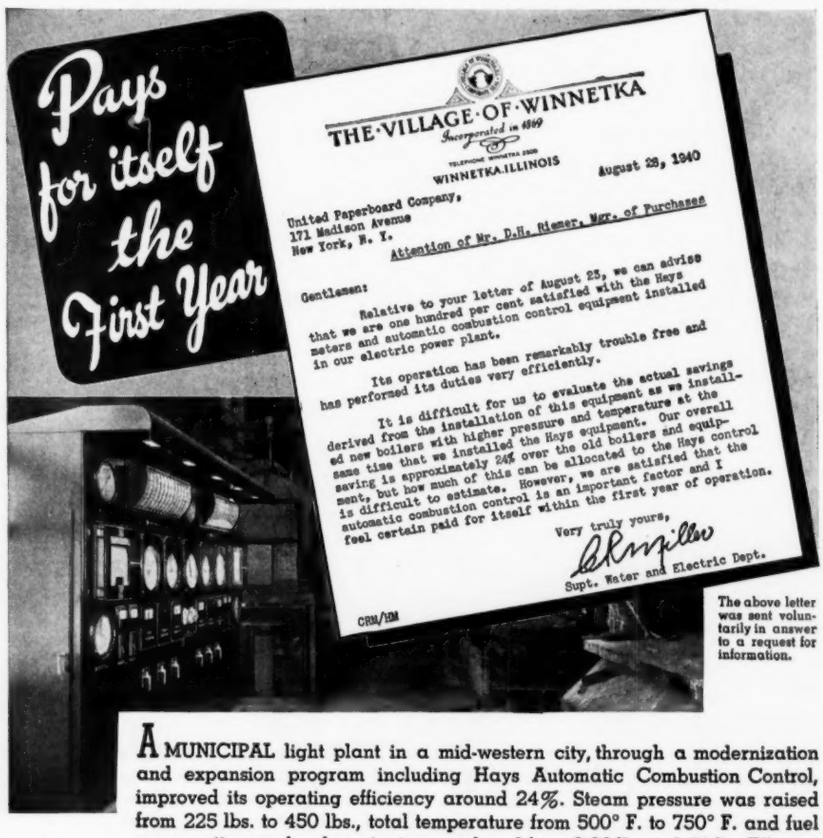
Marine Equipment

A 24-page catalog has just been issued by Combustion Engineering Company, Inc., covering its line of steam-generating equipment for marine service. Included are boilers of the sectional-header, the two-drum bent-tube and the three-drum straight-tube, or *A*, types; also, the C-E forced-circulation marine steam generator and the forced-circulation waste-heat boiler. The "Elesco" design of marine superheater and economizer, the C-E marine tubular air heater and the C-E marine-type spreader stoker are described.

The catalog is profusely illustrated with drawings and photographs showing details of the equipment described, and appended are shop views showing manufacturing operations in the fabrication and inspection of boilers at the Combustion Engineering shops.

Welding Fittings

Midwest Piping & Supply Company has issued a 40-page catalog covering its line of wrought- and forged-steel fittings. The bulletin (WF-41) is profusely illustrated and each type of fitting is accompanied by a dimensional diagram and a dimension, weight and price table. The fittings dealt with include butt-welding elbows, reducers, tees, tees reducing on run, crosses, 45-deg laterals, welding caps, return bends and shaped nipples, welding saddles and sleeves, lap-joint stub-ends and forged-steel flanges. Several pages also show photographs of typical installations and examples of pre-fabricated piping.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Incorporated in 1869
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August 23, 1940
United Paperboard Company,
171 Madison Avenue
New York, N. Y.
Attention of Mr. D.H. Riemer, Mgr. of Purchases
Gentlemen:
Relative to your letter of August 23, we can advise that we are one hundred per cent satisfied with the Hays meters and automatic combustion control equipment installed in our electric power plant.
Its operation has been remarkably trouble free and has performed its duties very efficiently.
It is difficult for us to evaluate the actual savings derived from the installation of this equipment as we installed new boilers with higher pressure and temperature at the same time that we installed the Hays equipment. Our overall saving is approximately 24% over the old boilers and equipment, but how much of this can be allocated to the Hays control is difficult to estimate. However, we are satisfied that the automatic combustion control is an important factor and I feel certain paid for itself within the first year of operation.
Very truly yours,
Supt. Water and Electric Dept.
CRH/HM

The above letter was sent voluntarily in answer to a request for information.

A MUNICIPAL light plant in a mid-western city, through a modernization and expansion program including Hays Automatic Combustion Control, improved its operating efficiency around 24%. Steam pressure was raised from 225 lbs. to 450 lbs., total temperature from 500° F. to 750° F. and fuel consumption per kw.-hr. output was reduced from 2.32 lbs. to 1.73 lbs. Efficient and economical combustion with practically no smoke or fly-ash is maintained by the Hays Automatic Control as well as a constant steam pressure regardless of load fluctuations.

NOTE TO ENGINEERS:

TEAR OFF THE BOTTOM OF THIS AD AND MAIL WITH YOUR NAME AND ADDRESS TO HAYS CORPORATION AND WE WILL SEND YOU A COPY OF "AUTOMATIC COMBUSTION CONTROL AND ITS RELATION TO LOWER STEAM COSTS."

Hays Engineering organizations throughout the country are ready to advise you how automatic combustion control may be able to improve the operating conditions in your own power plant—no obligation. Write us.

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MICHIGAN CITY, INDIANA, U.S.A.